

SELECTED ECOLOGICAL STUDIES ON CONTINENTAL SHELF BENTHOS  
AND SEA ICE FAUNA IN THE SOUTHWESTERN BEAUFORT SEA

by

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with

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I. Summary of objectives, conclusions, and implications with respect to OCS oil and gas development

A. Objectives

The research undertaken for OCSEAP and reported here covers two main scientific areas: (1) the trends in benthic fauna community structure with increasing depth and distance from shore and (2) the structure and dynamics of the nearshore sea ice faunal assemblage and its relationship to the benthos and zooplankton. Additional objectives include the characterization of organic flux to the sediments beneath the sea ice and the submittal of appropriate voucher specimens to the California Academy of Sciences.

B. Conclusions

Major components of the invertebrate fauna have been analyzed for cross-continental shelf trends in distribution, taxonomic composition, species richness and abundance. The macrobenthos (>1.0 mm) and megabenthos (>1.3 cm) exhibit opposite patterns in numerical density seaward of 5 m depth. The macrofauna are most abundant nearshore, while the megafauna are most numerous at the shelf edge and the upper part of the continental slope. The macrofaunal biomass peaks on the upper slope. The major components of the increased densities and biomass are polychaete worms, mainly Minuspio cirrifera for the macrofauna, and several species of ophiuroids for the megafauna. Species richness for five 0.1 m<sup>2</sup> grab samples for the polychaete worms and bivalve molluscs is maximum on the inner shelf. Species richness and total numerical density of polychaetes are high in shallow water in contrast to temperate open coastal environments. The low wave turbulence which is the result of damping effects of sea ice is suggested as the cause. The numerical density and biomass of the macro- and megafauna of the SW Beaufort Sea are similar to those found in rich environments in temperate environments.

As a number of the amphipods are abundant in coastal waters and are prominent members of the prey consumed by arctic cod and many fishes, this segment of the Beaufort food web is probably an important part of the food chain of key species of fish, birds and mammals. Assessments of this community provide a foundation upon which to base industrial decisions that impinge on the Beaufort Sea environment.

The flux of organic carbon to the shallow inner continental shelf communities is sufficiently high to provide an early source of newly-fixed carbon. The flux rates remain high throughout the spring period. Fecal pellets, particularly from the ice amphipod Pseudalibrotus (=Onisimus) litoralis, consist almost entirely of ice diatom fragments. Though several large particles can be identified and flux rates estimated, much of the organic material is of an unidentifiable detrital nature.

The benthic macrofauna is distributed roughly into a nearshore group (5-15 m depth) and a more widely spread shelf group of species. There are also outer shelf species at the edge of the continental shelf at depths of 70 to 100 meters. A study of the patterns of numerical densities of dominant species demonstrates that most broadly distributed species of bivalve molluscs, gammarid amphipods and polychaete worms have an optimum depth zone within which they are markedly more abundant. A number of species exhibit a bimodal pattern in abundance with the minimum centered at the region of the sea ice shear zone indicating that the ice gouging itself or secondary effects arising from this process causes a detrimental environmental stress.

The sea ice algal community appears to be an important source of carbon to the Beaufort Sea food web. Studies on the fauna associated with the undersurface of the sea ice during the spring months indicate that both meiofauna (63 µm-500 µm) and macrofauna (>500 µm) are present. In shallow oceanic waters, the meiofaunal groups increase significantly in numbers during May-June while benthic species of

amphipods are twice as abundant at the ice-water interface as on the sediments. Evidence indicates these animals are grazing on the pennate diatoms growing there.

Although the density of meiofauna within the ice is low compared to that typically found in sediments, it is much higher than had previously been reported from sea ice. Nematodes are the numerically dominant group, but copepods and turbellarians are also abundant. The life-histories of the two most numerous copepods have been examined and found to be very different. Cyclopina gracilis appears to reproduce continuously during the study, while Harpacticus sp. mates in the ice but does not appear to undergo a complete reproductive cycle there. An experiment was carried out to test the hypothesis that pelagic organisms prey on ice fauna, but the results are inconclusive.

### c. Implications

Extensive exploratory and production drilling for petroleum on the Alaskan and Canadian continental shelf has the potential to significantly influence the marine benthic environment and its associated biota. Although it is not possible to accurately predict the specific consequences of oil and gas development on the invertebrate species and the benthic food web, the addition of descriptive baseline data on species distribution, composition and abundance now permits refined estimates of the variability occurring within the benthic community through both space and time. It is these estimates which are necessary in sorting out the naturally-occurring changes in the biota from those induced by the future development of the petroleum industry.

The benthos of the Beaufort Sea continental shelf represents large concentrations of biomass that are potential food for many predatory organisms. As the benthic food web leads to many critical marine vertebrate species and to man, a determination of the distributional ecology and of biological rates is necessary for an understanding and modelling of the food webs of the sensitive species. Though environmental assessment decisions based on biological concerns may be made primarily on the species critical to man's food supply or to the environmentally concerned public, the benthos must also be considered in their role as a food source for many of these species. The distribution and abundance of benthic invertebrate prey may well affect the distribution, abundance, reproductive rates, growth rate and mortality rate of the critical vertebrate predators.

Biological rates dictate how much biomass is produced and, therefore, how much food will be available to predators. So little is known about the basic biology of marine organisms in the Arctic that static data based only on standing stocks does not reveal the level of available food supply. Large standing stocks of benthos could be comprised of old, slowly growing and slowly reproducing species. The time-series of benthic macrofaunal samples taken across the continental shelf along the standard OCS Pitt Point Transect now provides excellent material with which to explore some of these problems pertinent to the benthic food web. By determining the recruitment pattern of dominant species of a number of taxonomic groups across the shelf, estimates can be made of the reproductive rate of these species populations. Analyses of growth and mortality rates provide data on the biological activity and secondary production rates of dominant species. For instance, such analyses of gammarid amphipods that are known to be primary food sources for arctic cod yield basic data on the food supply to that fish under Beaufort Sea conditions.

The work on the epontic community has been a necessary step in understanding the role of the benthos in the arctic ecosystem. The degree of linkage between the under-ice and sedimentary communities has been examined to determine potential energy pathways and possible reproductive cues to the underlying benthic communities. The gammarid amphipods, the dominant members of the ice macrofauna, are important sources of food for arctic cod and other critical species, and these analyses add to our understanding of repopulation rates for benthic communities decimated by predators or by pollution events.

## II. INTRODUCTION

### A. General Nature and Scope of Study

Fundamental questions in the field of marine benthic ecology continue to involve causes for the spatial and temporal patterns of the distributions and abundance of species and species groups. While answers lie in both the processes involved with species interactions and in species-environmental relationships, correlative studies of species distributions and abundances along environmental gradients are a basic step in the initiation of such research. Insight into the relative importance of environmental and biological interactions can be obtained by contrasting similar data from differing environments and ecosystems.

Many such distributional studies have been undertaken in temperate waters, and sediment type, temperatures, depth, food input, currents and other environmental features have been implicated as basic physical and chemical influences on benthic ecological patterns in particular regions. However, there are few results reported in the literature contrasting data from markedly different environments that allow an evaluation of the relative importance of various aspects of the benthic environment. Over the last decade the benthic macrofauna has been studied extensively and aspects of the taxonomic composition and abundance are fairly well known in the southern Beaufort Sea (MacGinitie, 1955; Carey et al., 1974; Wacasey, 1974; Carey and Ruff, 1977; Bilyard and Carey, 1980). However trends in the benthos from the coastal zone to the deep-sea or of size classes other than the macrofauna are generally lacking. Trends in the abundance and species richness of the benthic macrofauna (1.0-13 mm) and megafauna (>1.3 cm) across a broad spectrum of bottom environments can provide insight into species environmental interactions,

The ability to predict benthic faunal distribution and abundance patterns provides a useful approach to estimating potential pollution problems associated with oil exploration and production on the Alaskan continental shelf. These patterns assume different scales depending on the size of animals, the degree of environmental disturbance, and the patchiness of the environment. Therefore, when possible the organisms from the width of the size spectrum should be studied for determination of ecological patterns for the community.

Benthic ecological studies on the Beaufort Sea continental shelf have included functional process-oriented research that is built upon an accumulated base of descriptive information on the invertebrate organisms and environmental measurements. Changes in the numerical abundance and biomass of the macrobenthos (1.0-13 mm) and megabenthos (>13 mm) have been examined at stations across the shelf. Research on the interrelationships between the underice epontic community and the associated sedimentary biota has been undertaken.

Concentrated study of the Beaufort Sea continental shelf benthic invertebrates was not initiated until the early 1970's. As very little was known about the fauna at the beginning of the exploration and developmental phases of the petroleum fields on the Alaskan North Slope, the early research involved basic survey work on the 1971 and 1972 US Coast Guard oceanographic cruises (WEBSEC-71 and WEBSEC-72). Detailed analysis of benthic communities and identification of the total polychaete worm fauna over a wide range of depths was accomplished. Further continental shelf survey sampling was then continued under the OCSEAP with the cooperation of the Coast Guard and their Beaufort Sea icebreaker program. With NOAA's interest and logistics support, seasonal sampling and study of temporal changes in the continental shelf communities was accomplished for the first time.

During the first year of operation a major objective was the summarization of literature and unpublished data pertinent to the Beaufort Sea. A significant amount of this information came from the work-up of the samples and the analysis of the data already on hand at Oregon State University as a result of the WEBSEC investigations. The objectives under the present research contract emphasize the delineation of the benthic food web and the description of the coastal benthos.

Much of the Beaufort Sea fauna has now been characterized at the species level, and detailed studies on temporal changes in the continental shelf benthic communities are underway.

Research has been undertaken in cooperation with other scientists which is oriented toward understanding the processes that maintain the nearshore and lagoon-al ecosystems. Of particular interest is the source of carbon that fuels the heterotrophic organisms living within the system. In lower latitude oceanic waters most of the carbon fixed by photosynthesis is ultimately derived from the phytoplankton, but in coastal waters much of the organic material may be land-derived. Water acts as a three-dimensional reservoir and transporter of organic carbon through a complex cycle that involves the interactions of numerous marine organisms. The benthos as an ecological group depend to a large extent on detritus that falls down to them. In the ice-covered waters of the Arctic, the epontic diatoms on the undersurface of the sea ice are an added source of carbon to the system (Homer, 1976), and in shoal waters benthic algae add to the primary production (Matheke and Horner, 1974).

The underice diatom bloom has been documented in coastal waters in the Chukchi Sea off Barrow, Alaska (Homer and Alexander, 1972), in the Eskimo Lakes region (Grainger, 1975), and in Stefansson Lagoon (Homer and Schrader, 1982). Though its areal extent either in coastal waters or offshore over the continental shelf is not known, it has been suggested that these epontic diatoms could be an important energy source within the southern Beaufort Sea ecosystem (Clasby et al., 1973). It is most pertinent to note that Schell (RU #537) recently measured substantial concentrations of chlorophyll on the undersurface of Beaufort Sea ice to a distance of 100 n.m. offshore (Schell, personal communication). The existence of the algal epontic community in oceanic waters suggests that primary production in this community is indeed energetically important to the total Beaufort Sea ecosystem. Although no direct measurements have been made, the pennate diatoms may fall to the sea floor upon ice melt in June (Matheke and Homer, 1974) thus providing a supplementary route for organic carbon to reach the benthos.

Numerous organisms have been sampled in association with the ice-sea water interface as the diatom bloom progresses through the months of April, May and June. Nematode worms are the most abundant, but harpacticoid copepods, amphipods and polychaete larvae have also been observed on the underice surface. The coastal amphipod Onisimus affinis, an important member of the demersal fish food chain, has been reported as migrating up to epontic community presumably to feed (Percy, 1975). Although the degree of linkage between the underice epontic community and the benthic community beneath is not known, it has been hypothesized that the sinking of detritus and diatom cells could provide a sizeable downward organic input to the underlying benthos. The vertical migration of benthic fauna up to the ice undersurface could provide these invertebrates with a significant source of energy-rich organics.

#### B. Specific Objectives

1. Analysis of the cross-shelf trends in the large macrofauna (>1.0 mm) and the megafauna (>1.3 cm) offshore of Harrison Bay.
  - a. Determination of the patterns of distribution, numerical density, biomass and feeding type of the benthic invertebrate fauna across the Alaskan arctic continental shelf.
  - b. Comparison of the ecological patterns of the arctic macrofauna (>1.0 mm) with those of the mega-epifauna (>1.3 cm) .
  - c. Comparison of the ecological patterns of the arctic benthos with those from temperate regions.
  - d. Evaluation of the controlling features of the arctic benthic environment.

2. Time-series laboratory studies on the meiofaunal ( $>63\ \mu\text{m}$ ) samples and large macrofaunal ( $>1.0\ \text{mm}$ ) samples from seasonal sea ice off Narwhal Island (1980).
  - a. Definition of the species composition and abundance of the ice meiofaunal community for the period 1 April through 10 June 1980.
  - b. Determination of the life histories of dominant ice harpacticoid and cyclopoid copepods for the period of study, April through 10 June 1980.
  - c. Description of the temporal changes in the ice macrofauna.
3. Analysis of organic particles collected at the benthic boundary during the 1980 sea ice faunal studies.
  - a. Identification and quantification of the particles.
  - b. Determination of the total flux of mass, carbon and nitrogen for the particle trap experiments.
4. Provide the California Academy of Science with a well-labelled, representative collection of benthic invertebrate species.

c. Relevance to Problems Associated with Petroleum Development

1. Cross-shelf Trends

Extensive exploratory and production drilling for petroleum on the Alaskan and Canadian continental shelf has the potential to significantly influence the marine benthic environment and its associated biota. Although it is not possible to accurately predict the specific consequences of oil and gas development on the invertebrate species and the benthic food web, the addition of descriptive baseline data on species distribution, composition and abundance now permits refined estimates of the variability occurring within the benthic community through both space and time. It is these estimates which are necessary in sorting out the naturally-occurring changes in the biota from those induced by the future development of the petroleum industry.

Detrimental impact on the marine environment and its associated biota is a major concern in offshore petroleum exploration and production. Potential environmental problems are very real in the southern Arctic Ocean (Beaufort Sea) where initial discoveries indicate significant oil concentrations under the inner continental shelf. The immense forces of the moving pack ice and the extremely cold temperatures accentuate the dangers of acute and chronic oil spills. These potential impacts cannot be sufficiently evaluated until the roles of various biological production processes in the polar ecosystem are known.

The benthos concentrated at the lower boundary of the oceans represents a potential source of food in the Beaufort Sea for a range of predators. Large standing stocks of benthic biota are found at the edge of the continental shelf (Carey and Ruff, 1977). Though many aspects of the benthic food web are unknown it is evident that the epibenthic crustaceans on the inner shelf are a segment of the benthic community that are pivotal in the food web leading to critical marine vertebrate species and to man (Griffiths and Dillinger, 1981). As the numerical density and standing stocks of organisms are the resultant of many biological processes, the determination of biological rates is also mandatory for a realistic energetic model of an ecosystem. Furthermore, the benthic food web may indirectly as well as directly influence the secondary production of marine animal species that are important to man. It is likely that the distribution and abundance of some of these critical species are influenced by the distribution and abundance of benthic prey species. Ultimately growth and mortality rates control biological secondary production rates of the dominant species. Such analyses of gammarid amphipods that



are known to be primary food sources for arctic cod can yield basic data on the food supply to that fish under Beaufort Sea conditions.

Life history information is relevant to management decisions concerned with environmental disturbance and the repopulation rates of the benthic communities in disturbed areas. If the nearshore fauna is reproductively already adapted to frequent environmental disturbance caused by storm wave turbulence or by ice gouging, an area subjected to an oil spill or other man-caused event might be expected to repopulate rapidly. Major changes in the benthic communities associated with a pollution event may therefore be found to fall within the limits of natural variability for these invertebrate populations.

## 2. Ice Fauna

Research on the underice epontic community in the Beaufort Sea has great relevance to environmental assessment decisions before, during and after exploratory and production phases of petroleum development. This potentially significant source of plant production and possible significant portion of the marine food web is open to large-scale and direct degradation by any under-ice oil spill. Specifically, it is evident from our 1980 spring studies seaward of Narwhal Island at a water depth of 9 meters that vagile benthic crustaceans such as the gammarid amphipod Pseudalibrotus litoralis swim up to the ice algal layer for grazing. Epibenthic crustaceans such as the gammarids are an important source of food for the young arctic cod (Sekerak, unpublished manuscript). It has been suggested by many authors (Clasby et al., 1973; Homer, 1976; Hameedi, 1978) that there is a downward flux of ice diatoms and detritus that provides food for the benthic fauna below. Indications point to a productive under-ice diatom community (Clasby et al., 1973; Homer, 1976; Dunbar and Acreman, 1980) that is widespread (Schell, personal communication) in Beaufort Sea waters and that may be a major link in the food web of many species of marine vertebrates and of man. Assessments of this community provide a foundation upon which to base industrial decisions that impinge on the Beaufort Sea environment.

In the hazardous arctic environment an oil well blowout or subsea pipeline rupture by a grounded ice ridge during the nine month ice-covered season could endanger the local ice biotic community and its associated food web. As the food web extends to marine mammals, birds and other top predators in the Beaufort Sea, the ramifications of detrimental pollution at the ice-water interface are essential to consider. Knowledge of the structure, function and ecology of the sea ice biotic community will aid in estimating possible damage and in developing techniques and technology to diminish such problems.

## 3. Particle flux

The falling of large particles provides the major mechanism for significant fluxes of organic materials, sediments, elements and contaminants. Large particle fluxes are significant in shallow waters in the Arctic (Carey, unpublished; Pett et al., 1983) and in temperate waters (Smetacek, 1980) and even to deep-sea depths (Honjo and Roman, 1978; McCave, 1975). Pollutants incorporated in, or adsorbed to, large particles could be rapidly transported to the sea floor and to the associated benthic communities. As amphipod and mysid crustaceans and other epibenthos are integral links in the arctic food web (Griffiths and Dillinger, 1981), oil spills and other man-caused pollution could be transported to the benthic food web via large particles. This is particularly likely for the particle link between the underice biotic community and the benthos beneath in shallow water. Pipeline ruptures and oil well blowouts during the ice-covered periods of the year would concentrate under the ice and be susceptible to bio-transport to the bottom during the growth phases of the ice community in the latter parts of the arctic spring.

#### D. Acknowledgements

The results included in this final report for RU #006 (NOAA/BLM Contract no. NA81RAC00061) represent the work of many in the field and laboratory. The results are derived from the 1976 R/V ALUMIAK, 1976-1977 USCGC GLACIER, and 1978 USGC NORTHWIND cruises in the SW Beaufort Sea and the 1980 fieldwork at the Narwhal Island ice station off Prudhoe Bay. R. E. Ruff was the mainstay in all phases of research; without him the research could not have been accomplished. On shipboard and at the Narwhal Island Ice Station, P. A. Montagna and P. H. Scott were indispensable during field operations. J. C. Kern and K. R. Walters worked hard and long at the ice station and OCSEAP Prudhoe Bay field lab. SCUBA diving services were provided by G. F. Smith of Coastal Environmental, Bellingham, Washington; J. Dougherty and R. Poirot undertook the long and strenuous dives for the ice fauna projects. K. Persons and S. Petersen provided logistic support at Prudhoe Bay for the project Sea Ice-80. Personnel from RU #359 were also a significant help during the April-June study period at the ice station. The NOAA helicopter pilots and mechanics are to be commended for their fine logistic support to the Narwhal Island Sea Ice-80 station. For shipboard operations we wish to thank the captain of the R/V ALUMIAK and the captains and crew of the USCGC GLACIER and USCGC NORTHWIND.

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K. H. Dunton provided samples of macro-algae, and G. Heron helped with copepod taxonomy. D. Schneider identified the mysid and amphipod fecal pellets.

### III. Current State of Knowledge

#### A. Benthic Fauna

With the discovery of large oil reserves on the North Slope of Alaska, fundamental ecological studies have provided extensive knowledge since 1971 of the benthic fauna of the southwestern Beaufort Sea. Numerous collections have been made of the littoral and shallow sublittoral fauna by Broad (1977), of the lagoon fauna (Griffiths and Craig, 1979), of shallow nearshore environments (Feder et al., 1976) and offshore environments (Carey, 1981; Frost and Lowry, 1983). This review concentrates on the offshore fauna.

Ecological patterns of distribution and abundance of the benthos have been synthesized as a result of surveys of infauna and epifauna across the southwestern Beaufort Sea continental shelf and slope (Carey, quarterly and annual reports 1976-1981, RU #006). The analysis of the distribution and abundance of the benthic macrofauna species was undertaken to define possible limits and zones of abundance of coastal shelf and outer shelf fauna. The shelf data were compiled from three OCS cruises from the summers of 1976-78 and the slope data from a 1971 WEBSEC cruise and the 1978 OCS cruise. From extensive studies of polychaete worms, gammarid amphipods and bivalve molluscs there are nearshore, outer shelf and upper slope faunal groups (Carey, 1981; Carey et al., 1984). The benthic macrofauna appear to be depressed in the 20-25 m depth range, probably caused by the direct and indirect effects of ice gouging into the bottom sediments. There is a maximum of numerical abundance and biomass of the macrofauna in much of the southwestern Beaufort Sea at the edge of the continental shelf and the upper continental slope (Carey and Ruff, 1977).

The degree of temporal variability of the benthic communities across the shelf is correlated with depth. The fauna at the shelf edge appear to undergo seasonal changes, though many dominant species of macrofauna reproduce at a low rate over a long period of time (Carey, 1981). Over a three-year period, a preliminary analysis of summer abundance of 25 species of bivalve molluscs and 24 species of polychaetous annelids indicates no marked changes in community structure. Rank order of abundance analysis demonstrates changes in the dominant species during the three-year period, but generally the dominant species tend to remain in the top three or four.

#### B. Ice Fauna

Detailed quantitative studies focused on arctic and subarctic ice fauna have been undertaken only in the last decade. Explorers and scientists on early expeditions to the Arctic observed amphipods and other organisms associated with ice and ice edge environments, but these observations were often incidental and vague (e.g., Nansen, 1906). Early taxonomic works (MacGinitie, 1955) and more recent quantitative and process-oriented studies on ice algae (Apollonio, 1965; Homer, 1977) also noted the types of fauna associated with ice living on the ice under-surface. Research on these faunal assemblages was first undertaken in the Arctic during the summer and fall of 1970 and 1973 by Golikov and Averincev (1977) along the coasts of Heve Island, Alexandra Land, Rudolph Island and Victoria Island in the Franz-Josef Land Archipelago in the Barents Sea. This extensive work utilized SCUBA diving to study the benthic and ice faunal assemblages on the shallow shelf.

Because Russian and Polish scientists were among the early workers in Antarctic ice faunal research (Gruzov et al., 1968; Rakusa-Suszczewski, 1972), it is not surprising that they also pioneered ice faunal research in the Arctic. Research on ice fauna began in Canadian and US waters in 1979 when Cross (1982) and Bradstreet and Cross (1982) undertook extensive studies of the marine ecosystem in Pond Inlet, Baffin Bay in the eastern Canadian Arctic. In 1979 Carey and Montagna (1982) also initiated ice faunal research in Stefansson Sound near Prudhoe Bay, Alaska in the

southern Beaufort Sea. Additional research was undertaken on the inner shelf seaward of Narwhal Island in the Prudhoe Bay region of Alaska (Kern and Carey, 1983; Carey, 1982; Boudrias and Carey, unpublished). Research on the animals associated with the undersurface of sea ice has continued in McKinley Bay on the Tuktoyaktuk Peninsula, southeastern Beaufort Sea (Pett et al., 1983), in Frobisher Bay 1979-1981 (Grainger and Hsiao, 1982) and at the pack ice edge in the Barents Sea (Gulliksen, in press). A more southern study was undertaken by Dunbar and Acreman (1980) in the Gulf of St. Lawrence; though the research was oriented toward the ice algae, observations were also made on the fauna. Dunbar had worked on arctic and subarctic zooplankton earlier and had summarized data on amphipod species known to associate with the sympagic environment (Dunbar, 1946, 1964).

Some of the earliest observations on animals associated with sea ice came from MacGinitie's extensive year-round systematic and natural history research on marine invertebrates in the Point Barrow, Alaska region from 1948 to 1950 (MacGinitie, 1955). He reported that numerous amphipods (Apherusa glacialis) lived under ice floes during the summer months in the northeast Chukchi Sea in the vicinity of the US Naval Arctic Research Station.

Other early observations on ice fauna came from workers involved in the multidisciplinary research conducted on the floating ice island research station T-3 (Mohr and Tibbs, 1963; Barnard, 1959) and from ice algal studies. Barnard (1959) reported on numerous amphipods captured beneath pack ice adjacent to the ice island by baited traps, but no direct observations were made on their in situ behavior and ecology at the ice undersurface. Data were not available from these early studies on absolute abundance, feeding behavior or thigmotactic affects of ice. Apollonio (1965) observed abundant gammarid amphipods that were "undoubtedly feeding on algae" while he was making collections on the ice undersurface near Devon Island in the Canadian Arctic for determinations of chlorophyll concentrations. Homer and Alexander (1972), Clasby et al. (1976) and Homer (1977) reported flagellates, heliozoans, hypotrichous ciliates, abundant nematodes, polychaete larvae, turbellarians, harpacticoid copepods and amphipods as part of the ice community. The amphipods were observed living on the undersurface of nearshore ice, and it was noted that their fecal pellets contained fragments of ice diatoms.

Once SCUBA diving in polar ice-covered waters was proven to be feasible (Peckham, 1964), quantitative studies on the structure and function of the sea ice communities became possible. The scientific field rapidly developed (Gruzov et al., 1968; Clasby et al., 1973) as the use of this diving technology permitted direct observation, quantitative sampling, and in situ experimentation. A number of specialized sampling devices have been utilized to sample the ice under-surface from above through holes augered in the ice (Gruzov et al., 1968; Rakusa-Suszczewski, 1972; Grainger and Hsiao, 1982). However, the ice-water interface consists of soft ice and fragile open crystalline structures (Kovacs and Mellor, 1974) that often cannot be effectively sampled or studied from above with standard coring devices (Clasby et al., 1973). The study of the arctic ice faunal community has developed so rapidly that much of the information collected remains unpublished and is available only in a variety of data reports, particularly those recently compiled for environmental impact assessment research oriented toward the oil industry for their oil exploration in offshore waters.

The true ice macrofauna (>0.5 mm) is almost entirely composed of gammarid amphipods (Griffiths and Dillinger, 1981; Carey, 1982). There appear to be four main macrofaunal sympagic communities: (1) the protected lagoon/bay fast ice community dominated by Gammaracanthus loricatus, (2) the shallow coastal fast ice community dominated by Pseudalibrotus litoralis, (3) the deeper seasonal sea ice zone fast ice community dominated by Apherusa glacialis, and (4) the old ice community dominated by Apherusa glacialis and Gammarus wilkitzkii.

The Apherusa community over deeper water contains larger numbers of amphipod individuals. The shallow fast ice sympagic community in the Beaufort Sea had a

mean of 10.4 amphipods per  $\text{m}^2$  (Carey, 1982; Boudrias and Carey, unpublished). The deeper fast ice community had a mean of 30.9 amphipod individuals per  $\text{m}^2$  in the Canadian Arctic (Cross, 1982). In the old ice community characterized by the amphipod species *Apherusa glacialis* and *Gammarus wilkitzkii* and studied in the Barents Sea by Gulliksen (in press), both numbers and biomass of the ice amphipods decreased significantly from the ice edge into the pack ice.

Both permanent and temporary meiofaunal organisms in the size range 63-500  $\mu\text{m}$  occur within the lower layers of the sea ice habitat. Meioplanktonic larvae of benthic polychaetes, pelecypods, gastropod, tunicates, turbellarians and cirripedes have been reported within the lower sea ice in the Arctic Basin (Grainger and Hsiao, 1982; Homer, 1977; Pett et al., 1983). Pett et al. (1983) reported spinoid polychaete larvae in the Canadian Beaufort Sea ice. Carey and Montagna (1982) found hesionid polychaete larvae in Beaufort Sea ice, including nectochaete larval stages that are probably capable of feeding on diatoms. Blake (1975) found that the juveniles of a similar hesionid species fed upon diatoms in the laboratory.

Permanent meiofauna including nematodes, harpacticoid and cyclopoid copepods, calanoid copepods, and rotifers have been reported as members of the sympagic community (Pett et al., 1983; Carey and Montagna, 1982; Kern and Carey, 1983; Cross, 1982). These organisms often occur in large numbers in most environments except in the ice in protected lagoons where the environment is highly variable (Carey and Montagna, 1982). In Stefansson Sound meiofaunal densities ranged from 4,500 to 8,000  $\text{m}^{-2}$ , whereas offshore in the fast ice the range was 36,000-320,000  $\text{m}^{-2}$  (Kern and Carey, 1983).

Nematodes are the dominant members of the ice meiofauna. In Pond Inlet, Baffin Bay, nematode worms accounted for 58.8% of the meiofauna (<1.0 mm) by number (Cross, 1982). In the shallow Beaufort Sea their numerical density exhibited an increase through the spring of 1980, and they ranged from 3,590  $\text{m}^{-3}$  in April to 62,360  $\text{m}^{-2}$  in June. Nematodes averaged 47.0% of the meiofauna during the study (Kern and Carey, 1983). There is little information available on the biology and ecology of the sympagic Nematoda. The strong trend in increasing population size through the spring suggests that these organisms are viable components of the ice community.

Copepods, mostly harpacticoids and cyclopoids, were the second most abundant group within the meiofauna in the lower ice environment. In the southern Beaufort Sea, these copepods comprised 28% of the meiofauna population by number (Kern and Carey, 1983), while in the eastern Canadian Arctic, they accounted for 39.7% of the small animals (Cross, 1982).

### c. Particle Flux

It has been conjectured that the downward transport of organic detritus, fecal pellets, crustacean molts and pennate diatom cells from the ice undersurface provides a food source for the pelagic and benthic faunas (Alexander, 1980, 1981; Golikov and Scarlato, 1973; Bradstreet and Cross, 1982; Homer and Schrader, 1982; Hameedi, 1978). The organic matter not consumed while sinking through the water column would be available to the benthos as food. The depth of water, the temporal pattern, and the flux rate of detrital sinking would influence the availability of degradable organics to the two faunas (Green, 1976). The supposition has been stated that during the melt season beginning in late May-early June, particles and algae slough off the bottom surface of the ice. In shallow water this sudden flux would provide an impulse of food materials to the sea floor as well as to the water column. In deep water less utilizable organic matter would reach the benthos. If the flux from the sympagic community takes place at a low rate over an extended period of time, more food could be utilized by the zooplankton on its way down to the bottom than if there was a sudden influx from the ice during accelerated ice melt in early summer.

Particles from the sympagic community reach the sea floor in shallow water throughout the winter and spring. In the Canadian Beaufort Sea pennate diatoms from the epontic algal assemblages were captured in near-bottom sediment traps in 6 to 19 m of water on the shelf offshore of the Mackenzie River and in McKinley Bay, a shallow coastal embayment in the ecological transition zone (Pett et al., 1983). Algal cells increased from  $4 \times 10^6$  cells  $m^{-2}day^{-1}$  to  $28 \times 10^6$  cells  $m^{-2}day^{-1}$  in May-June. However, total particulate flux of carbon and nitrogen does not seem to be affected by the accelerated loss of the ice algal community from the ice under-surface in early June (Pett et al., 1983; Carey, unpublished). The carbon flux to the sediments through a 7 m water column in the southern Beaufort Sea off Narwhal Island varied between 29 and 48 mgC  $m^{-2}day^{-1}$  with no significant trends or correlations with environmental events. Nitrogen flux was low, 1.5 to 6.2 mgN  $m^{-2}day^{-1}$  and erratic throughout the spring season. Fecal pellets from the grazing sympagic amphipod Pseudalibrotus litoralis contained high concentrations of pennate ice diatom frustules; their flux to the bottom increased from April through May, 1980 and then fell almost to zero in early June. The carbon and-nitrogen data indicate that there is no sudden influx of organic materials to the benthic environment during the melting period but rather there is generally a high and continual rain of organic matter to the bottom throughout the spring growing season.

#### IV. Study Area

As part of the Arctic Ocean, the Beaufort Sea along the Alaskan north slope is subject to extensive ice cover during much of the year. Normally the sea ice melts and is advected seaward in July and August in response to regional wind stresses, but in some years the polar pack can remain adjacent to the coastline throughout the entire season. The extent of ice cover during the sunlit summer months affects wind mixing of surface water and the penetration of light into the water column. These factors affect the onset and intensity of phytoplankton production which is highly variable and generally of low magnitude (Homer, 1976; Clasby et al., 1976). The keels of sea ice pressure ridges cause significant disturbance to the benthic environment by plowing through the bottom sediments as they are transported across the inner shelf by the currents and prevailing winds (Barnes and Reimnitz, 1974; Reimnitz and Barnes, 1974).

Generally, the bottom water masses of the southwestern Beaufort Sea are stable, and except for the shallow coastal zone, differ little in thermohaline characteristics throughout the year (Coachman and Aagaard, 1974). However, the outer shelf region from Point Barrow to about 150°W is influenced by Bering-Chukchi water that is advected as a subsurface layer and moves around Point Barrow throughout the year in pulses controlled in part by atmospheric pressure gradients (Hufford et al., 1977). Coastal upwelling has also been observed in the Barter Island region during a summer when the pack ice had moved relatively far offshore (Mountain, 1974).

A unique habitat exists within the lower layers of polar and subpolar sea ice. The bottom ice layer has been described as being soft (Homer, 1976), or loose (Andriashev, 1968) in composition, in contrast to the hard ice above. It has relatively constant temperatures (-3 to 0°C), enough nutrients to support algal growth, variable osmotic pressure, and a probable abundance of organic material (Meguro et al., 1967). Seasonal ice is generally 2.0 to 2.5 m thick, yet sufficient light of adequate quality passes through it to support photosynthesis within the ice habitat (Maykut and Grenfell, 1975). Multi-year (pack) ice is generally thicker, but the presence of chlorophyll within the lower ice layers (English, 1961) is evidence that photosynthesis also occurs in this ice. Pack ice is present all year, and therefore provides a permanent environment in which ice organisms can survive. Seasonal ice breaks up each year in late spring, so that organisms within the lower layers of this ice exist in an ephemeral habitat. Despite the temporary nature of the seasonal ice environment, an abundance of life can be found there.

During most of the year in oceanic waters, arctic ice generally exists as a mixture of old and new ice. Because of the dynamic forces involved, newly formed thin pack ice can exist adjacent to multi-year ice floes and pressure ridges tens of meters thick (Zubov, 1943). As age and thickness of the ice increase, its crystalline structure, salinity and light transmissivity change. Age and deformation of ice, therefore, are other characteristics necessary for consideration in defining ice habitats.

The specific study areas in the southwestern Beaufort Sea reported upon in the following results sections include: (1) a broad transect line of stations in the vicinity of Harrison Bay, SW Beaufort Sea (Figure 1), and (2) a shallow diving station occupied in the frozen spring months offshore of Narwhal Island (Figure 2). The Pingok Island Cross-Shelf Transect includes a range of environments from the inner continental shelf at 5 m depth to the deep-sea at 1800 m depth on the continental slope. The Narwhal Island Ice Station is an oceanic environment just seaward of the barrier island. It is in the seasonal sea ice zone and is within the depth range directly influenced by sea ice gouging.

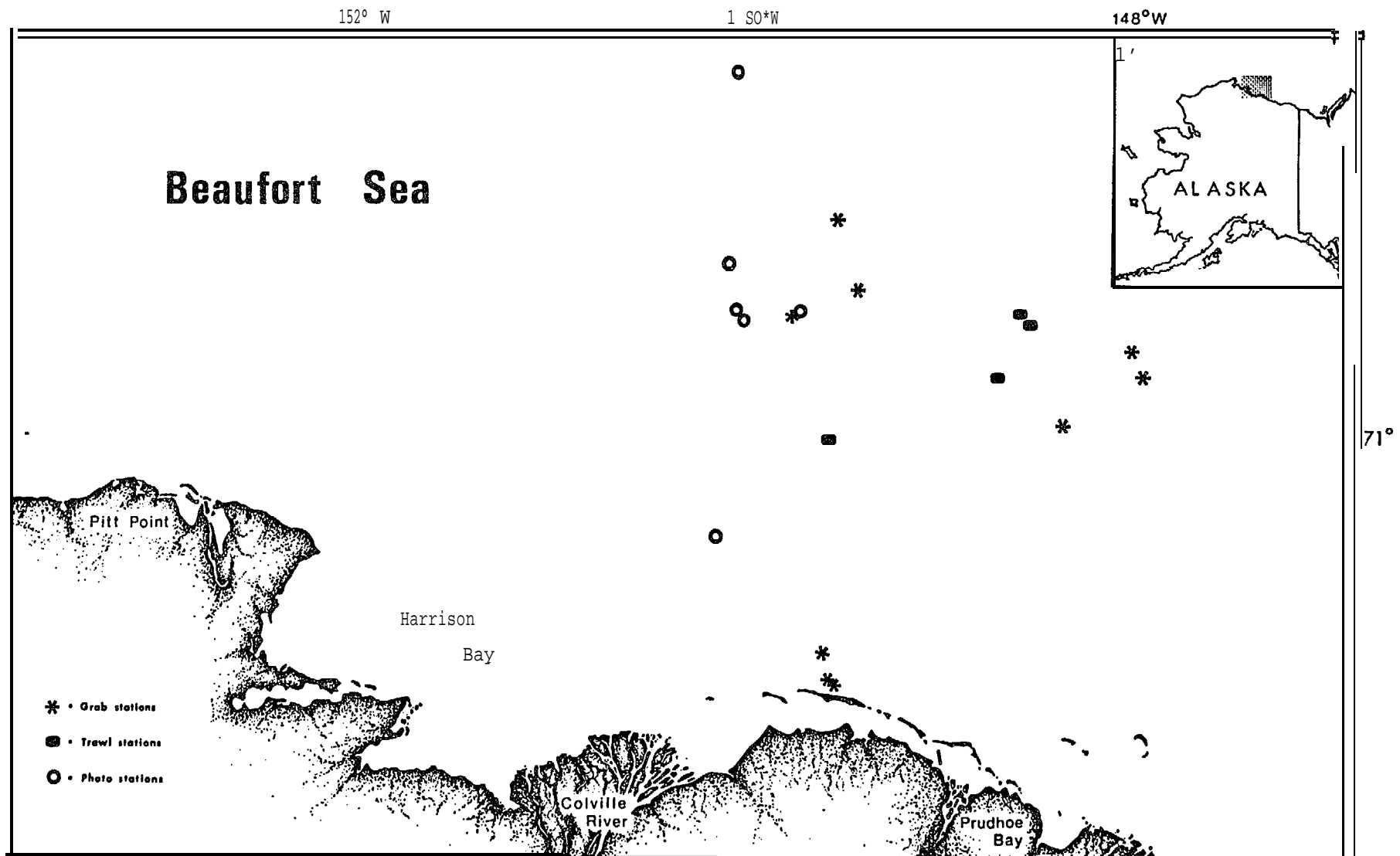


Figure 1. Location map for grab, trawl and photographic stations on the cross-shelf transect in the SW Beaufort Sea.



## V. Sources, Rationale and Methods of Data Collection

### A. Sources and rationale

#### 1. Benthic continental shelf fauna

There has been a need to define cross-shelf trends of benthic fauna with as complete a description of the community as possible to include major components of the benthic food web. As much data as possible has been put together to synthesize faunal changes along environmental gradients. By combining data from otter trawls, stereo bottom photography and bottom grabs, trends across the shelf in both the macrofauna and megafauna have been synthesized. Without this combined approach data from various depth zones would have been incomplete because of sampling problems caused by sea ice during the summer cruises.

#### 2. Ice fauna (Narwhal Island)

The epontic (sympagic) sea ice faunal community has been examined in detail because of its importance in the Beaufort Sea ecosystem during the spring months. Gammarid amphipods are the major component of the ice macrofauna and these organisms are important prey for the arctic and glacial cod, pivotal higher carnivores in the oceanic food web. The Sea Ice-80 fieldwork off Narwhal Island in conjunction with RU #359 provided an extensive collection of meiofaunal and macrofaunal samples that form the basis of an intensive time series study of the ice, midwater and sea floor fauna.

#### 3. Particle flux

Because the role of the spring ice community in the arctic oceanic ecosystem is unknown, energetic links between the ice subsurface and the sea floor have been investigated. As detailed by such researchers as Honjo (1980) and Suess (1980) large particles account for a significant portion of the downward flux of sediments and organic carbon and nitrogen. Collection of large particles at the benthic boundary beneath the ice by sediment trap at the Narwhal Island ice station provides data to assess the input of detrital carbon and nitrogen to the benthic community.

### B. Field and Laboratory Methodology

#### 1. Benthic continental shelf fauna

##### a. Macrofauna

The macrofauna were collected by 0.1 m<sup>2</sup> Smith-McIntyre bottom grab (Smith and McIntyre, 1954) at 10 stations from 5 to 1800 m depth in a broad transect across the continental shelf and upper continental slope (Appendix I: Table 4). Five quantitative samples were obtained from each station; only those samples with an unwashed appearance and with a minimum of 3.5 liters of sediment were retained for analysis.

Grab samples were washed on board ship through 1.00 and 0.42 mm screens, and the material retained on the sieves preserved in 10% formalin neutralized -with sodium borate. Rigorous procedures for field sample collections were maintained during all phases of the project to ensure sample integrity. Field data sheets were completed at the time of collection to record observations on sampling conditions, sample quality, and biological information of note. The samples were routinely double labelled to minimize confusion, and complete field as well as laboratory log books were maintained. Careful preservation techniques were followed for proper fixation of the tissues, and the samples were shifted to 70% ethanol in the laboratory for long-term storage. Sampling adequacy was addressed through accumulation curves for total number of species, absolute number of specimens, and total biomass. Five 0.1 m<sup>2</sup> grab samples now appears to be the minimum number at most shelf depths to adequately describe the benthic macrofaunal species composition.

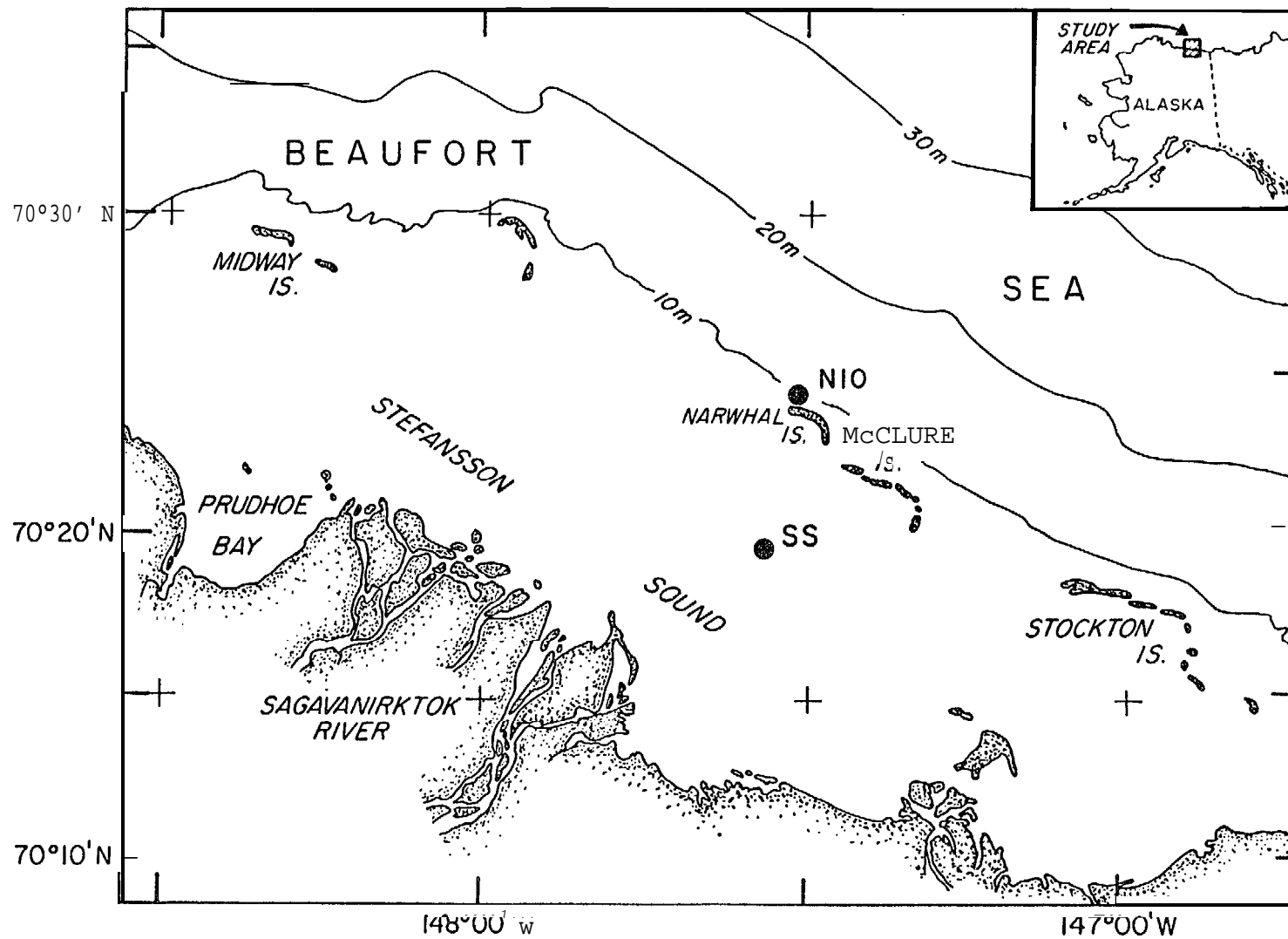


Figure 2. Location map for the Narwhal Island ice station (NIO) for Project Sea Ice-80. Station SS designates the location of the 1979 pilot study on ice fauna at the Boulder Patch.

Standard analytical methods were employed to process the Smith-McIntyre grab samples in the laboratory. The quantitative samples were sieved into two fractions, including the large **macro-infauna** (>1.00 mm) and the smaller **macro-infauna** (0.5-1.00 mm). The organisms in the larger fraction were picked from the sediment particles and organic debris under a dissecting microscope, and sorted to major taxonomic category. The organisms were then enumerated, wet-weighed, and the dominants were identified to the species level as far as possible. Verification of species identifications were solicited from taxonomic specialists whenever necessary. For selected stations the small **macro-infauna** organisms (0.5-1.00 mm) were also picked, sorted, identified and enumerated to provide essential life history data on the juveniles of the dominant species.

b. Megafauna

1) Trawl collections

The megafauna were sampled by qualitative 4 m semi-balloon Gulf of Mexico shrimp trawls with stretch mesh, used when possible with a 1.3 cm stretch mesh liner. Summer sea ice conditions dictated the length and direction of each tow, and prevented the collection of standardized net tows for comparative purposes or abundance estimates. Samples were obtained, however, from each of 6 stations from depths of 28 to 360 m during the summers of 1971 and 1972 (Appendix I: Table 5).

2) Bottom photography

Photographs were taken with an Edgerton stereo deep-sea camera system during the summer of 1972 (Appendix I: Table 6) during the US Coast Guard WEBSEC field work. Bottom photography was utilized as an ultimate approach for the acquisition of quantitative data for visible **mega-epifauna**. When ice conditions excluded the use of towed trawls, quantitative abundance data were obtained for the visible megafauna. An Edgerton stereo deep-sea camera system (Model 205) on automatic tuned sequence was flown within 1.0 to 12.0 meters of the sediment surface. Visible fauna in the photographs were identified to major groups when further definition was not possible and to species when positive identification could be made based upon the otter trawl collections from the same area.

2. Ice fauna (Narwhal Island)

a. Meiofauna

1) Ice undersurface

Ice meiofaunal samples were collected on nine occasions between 14 April and 5 June, 1980 (Appendix II: Table 17). A 36 m<sup>2</sup> area, approximately 18 m from a tent-covered dive hole, was staked out on the undersurface of the ice with a rope marked in 0.5 m increments. This divided the study area into a grid containing 144 0.25 m<sup>2</sup> quadrats. Sampling locations within this area were assigned using coordinates taken from a random numbers table. Samples from 24 April and 11 May were taken slightly outside the study grid. Ice samples collected on 14 April and 5 June were taken an unknown distance within 40 m of the study area (Kern, 1981).

Quadrats were sampled by a diver, using SCUBA, with a corer of 10.5 cm id. This sampled an 86.6 cm<sup>2</sup> area of the undersurface of the ice. One end of each corer was covered with 64 micron mesh. The open end was pushed into the undersurface of the ice until hard ice was reached. Cores were contained by sliding a spatula into the ice over the end of the corer, and then capped while underwater; quadrats were never sampled more than once. Samples from 14 April and 5 June were collected using an ice scraper (Carey, 1981), rather than a corer, and could not be compared quantitatively with the cores.

Samples were placed in jars and transported to the lab where they were washed on a 64 micron sieve. Animals were preserved in 10% buffered formalin and stained with rose bengal. Core samples were sorted into major taxonomic groups and enumerated under a dissecting microscope. Only taxa of sizes large enough to be consistently retained on a 64 micron mesh were enumerated since the sample could not be regarded as being quantitative for smaller organisms. Calanoid copepods, which

were found infrequently in cores and always in low numbers, were also not counted since it was unclear whether they were present in the ice or caught in the corers prior to being inserted into the ice. **Cyclopoid** and **harpacticoid copepods** were identified to the species level. It was not possible in the time available to identify each **copepodite** stage. Instead, all undamaged individuals belonging to the two dominant copepod species were measured to the nearest 24 microns using an ocular micrometer. Total length, excluding the terminal setae, of these organisms was measured. One hundred individuals of each of these species were randomly chosen from the ice scraper samples and measured. The presence of egg sacs and **pre-copulatory** clasping pairs was recorded for these species on all sampling dates. The gender of all individuals large enough to be sexed was recorded.

Cores taken from the ice undersurface were used for density estimates of the fauna, for collection of species used for life-history studies, and as controls for comparison with cores from caged areas of the ice (Kern, 1981). Ice scraper samples were used only for the **copepod** life-history studies.

A one-way analysis of variance was used to test for changes over time in the density of major taxa and copepod species. A multi-variate analysis of variance (Cohen and Burns, 1977) was used to test for differences in the density of major taxa and copepod species between caged and uncaged ice. Data were  $\log_{10}(x+1)$  transformed before the above tests were performed. The Kolmogorov-Smirnov test (Tate and Clelland, 1957) was employed to test whether the population size structures of the dominant **copepod** species changed over time. The size-frequency distribution at each sampling date was compared separately with the distribution of the preceding date, as well as the following date. Since the same data set was tested several times, the chance of making an error by incorrectly rejecting the null hypothesis of no difference in population structure was increased. Therefore, to be conservative, the level of significance used to reject the null hypothesis was preset at 0.01.

## 2) Midwater collections

Quantitative collections were made of the large meiofauna in **midwater** with a 0.75 m ring net on a pulley and line arrangement (Homer and Schrader, 1981). Replicate tows were made with a technique which standardized the time, speed, depth, distance and net orientation. The mesh of the zooplankton net was 308  $\mu\text{m}$ ; therefore, only the largest of the permanent meiofauna were retained quantitatively by the net.

### b. Macrofauna

#### 1) Ice undersurface

The underice macrofauna were collected by SCUBA divers with hand-held open-mouth nets. The mesh size was 0.5 mm, and the net width 10 cm. The net was pushed along the undersurface of the ice in a straight transect 10 m in length. The area sampled per haul was 1.0 m<sup>2</sup>. Five replicates were taken during six sampling dates- 13 April, 19 April, 5 May, 17 May, 31 May and 9 June, 1980 (Appendix II: Table 18).

The samples were washed into jars in a heated tent at the field station and brought back to the OSCEAP field laboratory at Prudhoe Bay, Alaska. The samples were washed through a 0.5 mm sieve, and 10% formalin buffered with sodium borate was added. Crustaceans were later identified (Appendix II: Table 19) using the following references: Barnard, 1969; Sars, 1895 and 1918; Stephensen, 1923, 1925, 1931 and 1944; and Gurjanova, 1951.

#### 2) Midwater collections

**Macrofauna** (>0.5 mm) were quantitatively collected by 0.75 m ring zooplankton net with 308  $\mu\text{m}$  mesh. The ring was attached to a line and pulley system anchored to a wooden post mounted through the ice 14 m away from the dive hole (Homer and Schrader, 1981).<sup>21</sup> Net tows were standardized to sample at 3 m depth at a speed of about 0.15 msec. The samples were washed into jars at the field tent. At the OCSEAP lab in Prudhoe Bay the samples were washed on a 0.5 mm sieve and preserved

in 10% formalin buffered with sodium borate. Sample tows were made in pairs. On four occasions the standardized tows were made every two hours over a 24 hour period to determine the temporal pattern of amphipod abundances in the water column. These time series studies were made 30 April-1 May, 7-8 May, 19-20 May, and 2-3 June, 1980.

### 3) Sediments

Macro-epibenthic fauna were collected by SCUBA diver with the same 10 cm flat bottomed nets as those used on the undersurface of the sea ice (Appendix II: Tables 20-23). Five net hauls were made per sampling period over 10 m long transects; each transect haul covered 1 .0 m<sup>2</sup>. At the end of each transect run the net was folded over the metal frame to retain the sample. The samples were washed on a 0.5 mm seive and were preserved in 10% formalin neutralized with sodium borate.

#### 3\* Particle Flux (Narwhal Island)

Large particles were collected as close as possible to the sediment-water interface with cylindrical particle traps with an inside diameter of 13.1 cm and a height of 39 cm above the collecting surface. The traps, therefore, had an aspect ratio of 3:1. This has been determined as the correct configuration to minimize resuspension by water turbulence within the sampling cylinder (Gardner, 1980). A prefired and preweighed glass fiber filter was placed at the bottom of each cylinder over a porous filter bed, through which the water retained in the cylinder could be drained.

Eight traps, four in each of two weighted frames were deployed seven times from 17 April through 5 June, 1980. SCUBA divers placed the two trap arrays on the sediment surface with the aid of sponges flotation. They were located to the south of the dive hole in a sector of the study site chosen to have minimal disturbance from the other diving operations undertaken for the Sea Ice-80 studies (Figure 3). The cylinders contained filtered seawater and were capped during deployment. Upon retrieval the caps were replaced on the cylinders by the divers before moving them to minimize contamination problems.

In the field laboratory, the inside of the cylinders was washed down with filtered fresh water, and the remaining moisture was pulled through the glass-fiber filter pad by gentle suction. The cylinders were disassembled and the filters removed in a protective work hood made of plastic sheeting to minimize contamination. With the aid of forceps, each filter sheet was carefully placed in a separate pre-labelled, sterile, plastic petri dish for transport to Oregon State University. Upon removal from each cylinder the filters were stored in a deep-freezer and kept frozen during shipping and later storage.

Laboratory analyses included particle counts, particle weights with a correction for NaCl, measurement of organic carbon and nitrogen, and identification of particle type and particle qualitative composition by scanning electron microscopy. These data were then used to calculate the flux of carbon, nitrogen and identifiable particles to the sea floor beneath the ice.

Counts of particles were made on each thawed filter with 6x magnification under a dissecting microscope without removing the filter from its sterile petri dish (Appendix III: Table 29). Selected recognizable particles were counted and measured with an ocular micrometer.

The total mass of particles on each filter was measured by drying the filters in a drying oven at 65°C to constant weight. Weights were then measured to the nearest ±0.001 g. For the salt correction three 1.629 cm<sup>2</sup> subsamples were removed from each of the filters and soaked in 10 ml of 0.3N HCl. Magnesium concentrations in the subsamples were measured against dilute seawater standards with a flame spectrophotometer. The weight of sea salt for each sample was then calculated.

The amount of carbon and nitrogen contained on the collection filters was measured in four 1.629 cm<sup>2</sup> subsamples removed from each filter. The subsamples

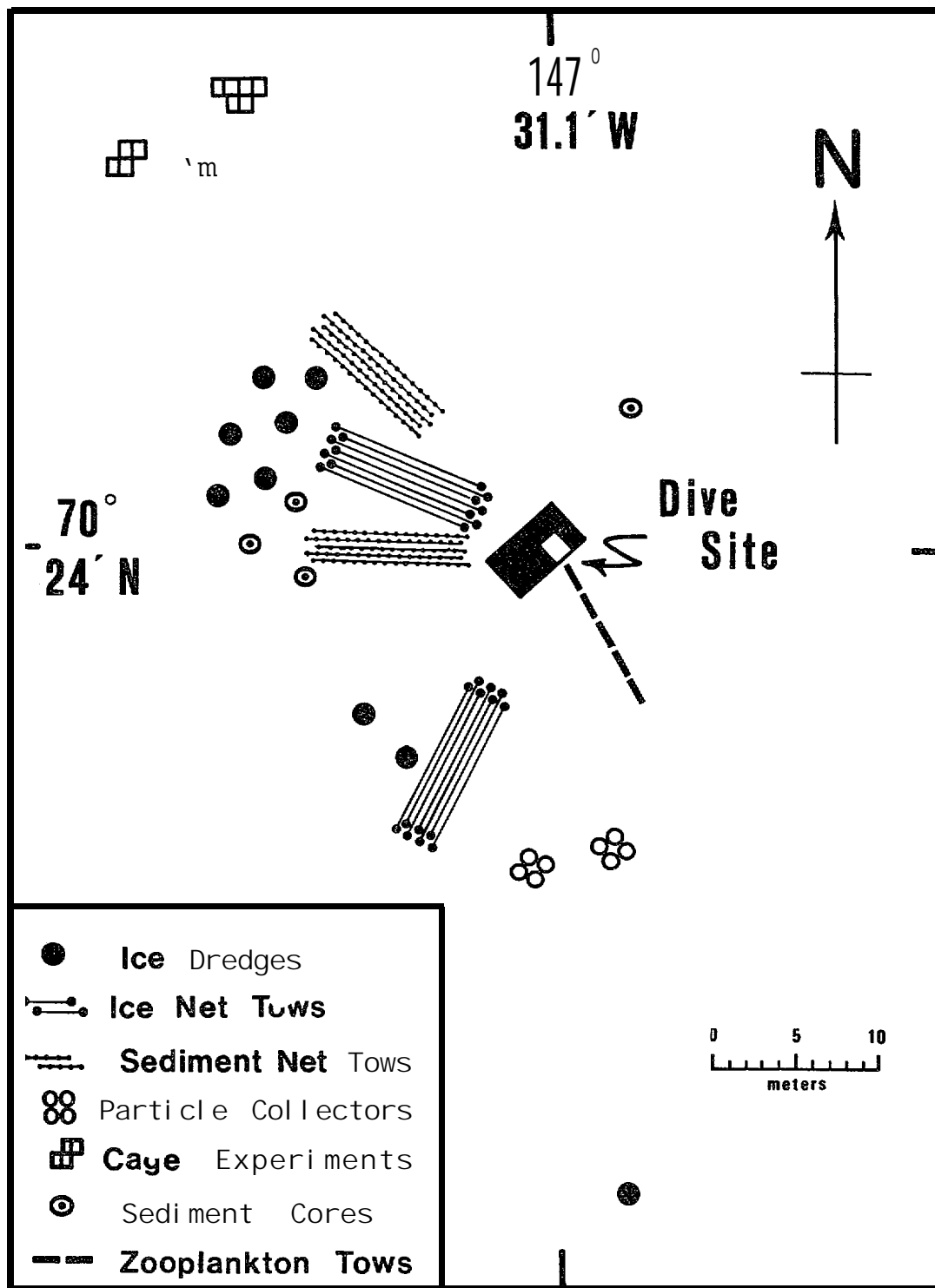


Figure 3. Narwhal Island ice station for Project Sea Ice-80. Note the dispersion of locations to minimize inter-project disturbance. RU #359 utilized the northwestern sector for ice algal studies.

were burned in a CHN Analyzer to determine the weights of the contained carbon and nitrogen in pg.

Subsamples (0.595 cm<sup>2</sup>) were removed from areas of interest on the filters for scanning electron microscope study. These were dried, mounted and sputter-coated with Au/Pal, and then examined and photographed at a range of appropriate magnifications (see Appendix III: Figures 57-63).

Calculations were then made to determine the flux per unit area and per day for the recognizable particles, carbon, nitrogen and total mass.

#### 4. Environmental data (Narwhal Island)

Temperature and salinity were measured throughout the study period with a Kahl Scientific Company electrodeless salinometer (Model RS5-3). The salinometer was modified to measure temperatures down to -2.0°C, though minimum temperatures below this value were probably reached. The sensor unit was lowered to depths about 30 cm below the ice-water interface and the same distance above the sediments to minimize interference with the inductive salinometer functioning (Kahlsico, 1975). Measurements were made at 1 m increments down to the sediment (Appendix II: Table 24).

## VI. Results

### A. Benthic continental shelf fauna: cross-shelf trends.

The total numerical density of macrofauna (means  $\pm$  standard deviation) demonstrate a bimodal pattern (Figure 4 and Appendix I: Tables 7-10). The maxima at 10 m and 700 m depth and the minima at 5 m and 1800 m depth are statistically significant. The 10 m peak is significant at the .001 level. The annelids are the dominant taxonomic group at most stations, though the molluscs predominate at 3 stations at 23, 100 and 1800 meters depths (Figure 5).

The macrofaunal biomass generally follows an increasing trend of abundance with depth to the outer shelf and upper slope with a subsequent decrease to low standing stocks at 1800 m (Figure 6 and Appendix I: Tables 11-13). The high biomass at 15 m depth is an artifact directly attributable to the thick shells of the bivalve mollusc Astarte montagui.

Polychaete species generally have broad distributions across the southwest Beaufort Sea continental shelf, with one or more maxima of numerical abundance (Figure 7 and Appendix I: Table 14). For example Minuspio cirrifera is very abundant at both the 10 and 700 m depth, while Chone nr C. murmanica is most abundant at 47 m. The 15 m depth station appears to have depressed polychaete populations which may be caused by severe ice grounding in this zone. Such variability also indicates the patchiness of the fauna, environment, or both. Note that Capitella capitata, a species indicative of environmental disturbance, is found in the near-shore zone. Pelecypod mollusc species are also found across broad areas of the shelf, though the species populations are generally abundant only in a narrow depth zone (Figure 8). Dominant species of polychaetes and bivalves can, therefore, be used to characterize portions of the shelf and upper slope environments.

Species richness (number of species per station) is highest at the intermediate depths (10-100 m) for both the Polychaeta and Pelecypoda with minimal diversities at the shallowest station (5 m) and the deeper stations (200 to 1800 m) (Figure 9).

A study of feeding types of polychaete worms emphasizes the increasing importance of subsurface deposit feeding species with increasing depth (Figure 10). Surface deposit feeders are most abundant at the shelf edge and decrease down to the 1800 m depth.

Megafaunal invertebrates are most abundant on the outer continental shelf and uppermost part of the Beaufort Sea continental slope (Figure 11). Though these quantitative data are limited to the visible fauna seen in bottom photography, otter trawl collections indicate that these fauna are the predominant grazers in the megabenthic community. Ophiuroids are the dominant group and compose a large proportion of the large fauna (Figure 12 and Appendix I: Figures 44-54). Ophiacantha bidentata can be identified from the photographs because of its unique appearance, though the genera Ophura and Ophiosten could not be differentiated in the photographs. Note the abundance estimates of ophiuroids from both the photographic counts and the grab data characterize the outer shelf-upper high slope standing stocks. Grab and photographic ophiuroid abundance estimates for the shallowest station (25 m) may differ because of the increased turbidity in onshore waters that lowers photographic contrast and definition due to light backscatter from suspended particles. This band of high ophiuroid abundance is correlated with areas of postulated higher sedimentation rates (Carey et al., 1974).

The depth distributions of mega-epifauna are generally broad (Figure 13). Species distribution data compiled from both the trawl collections and the bottom photographs demonstrate these trends. The shallow stations support few species of megafauna; the distribution of this ecological group tends to be shifted toward deeper water.



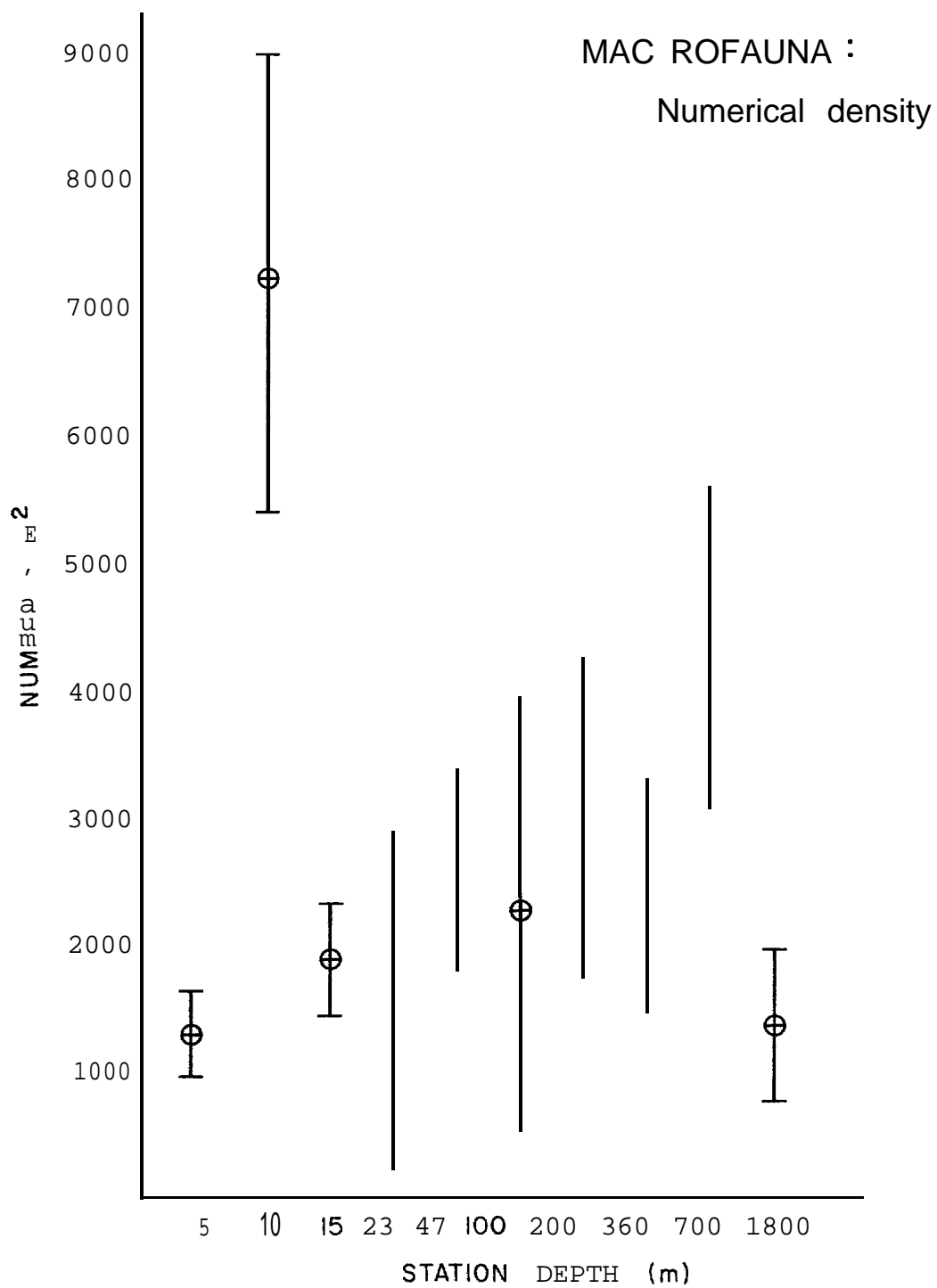


Figure 4. Numerical density of benthic macrofauna (>1.0 mm) on the Pingok Island cross-shelf transect. Means  $\pm$  1 standard deviation. N = 5 per station.

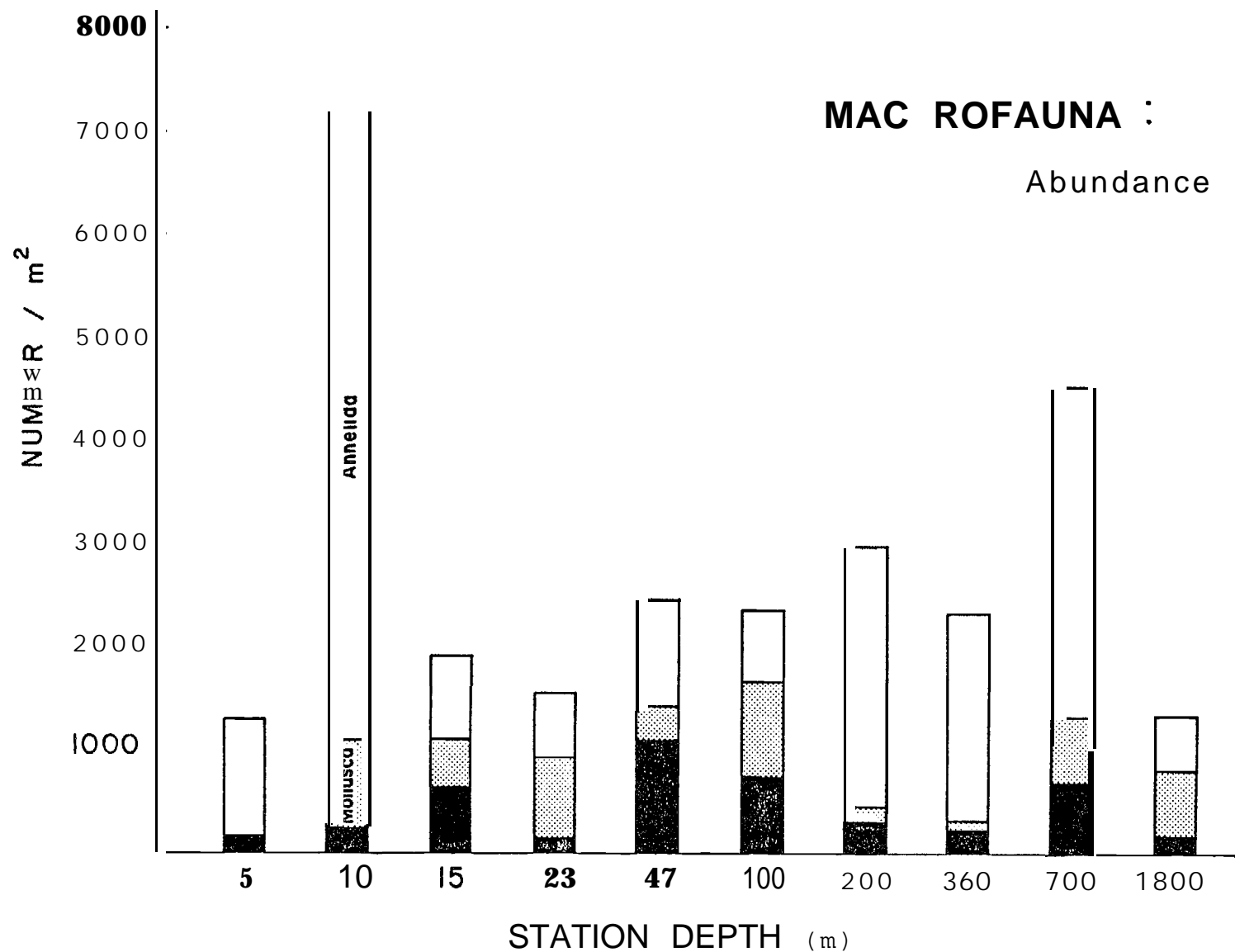


Figure 5. Abundance of benthic macrofauna on the Pingok Island transect to demonstrate cross-shelf trends of the two dominant major taxa, Annelida and Mollusca.

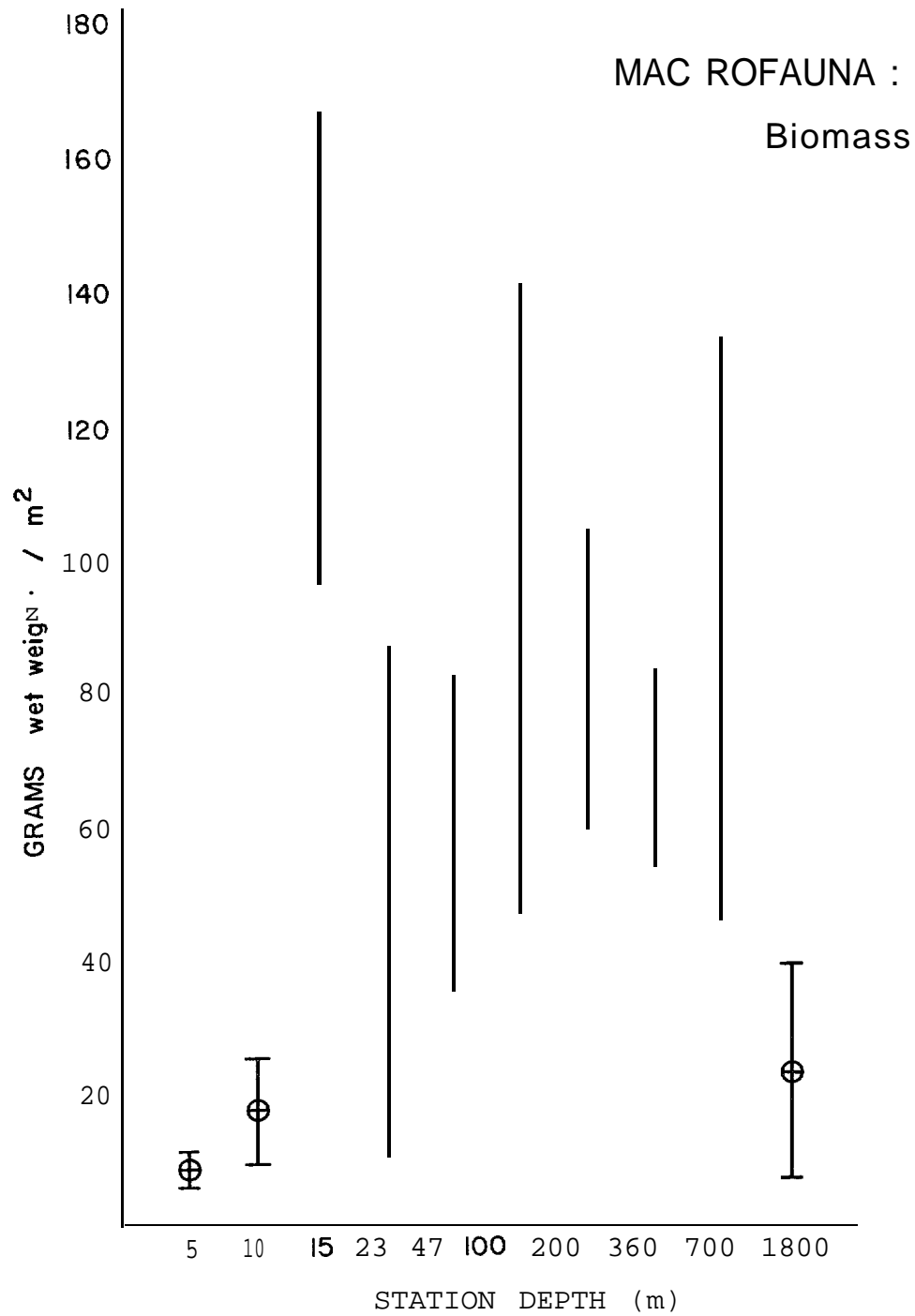


Figure 6. Standing stock biomass (wet-preserved weight) of benthic macrofauna on the Pingok Island cross-shelf transect. Means  $\pm 1$  standard deviation. N = 5 per station.

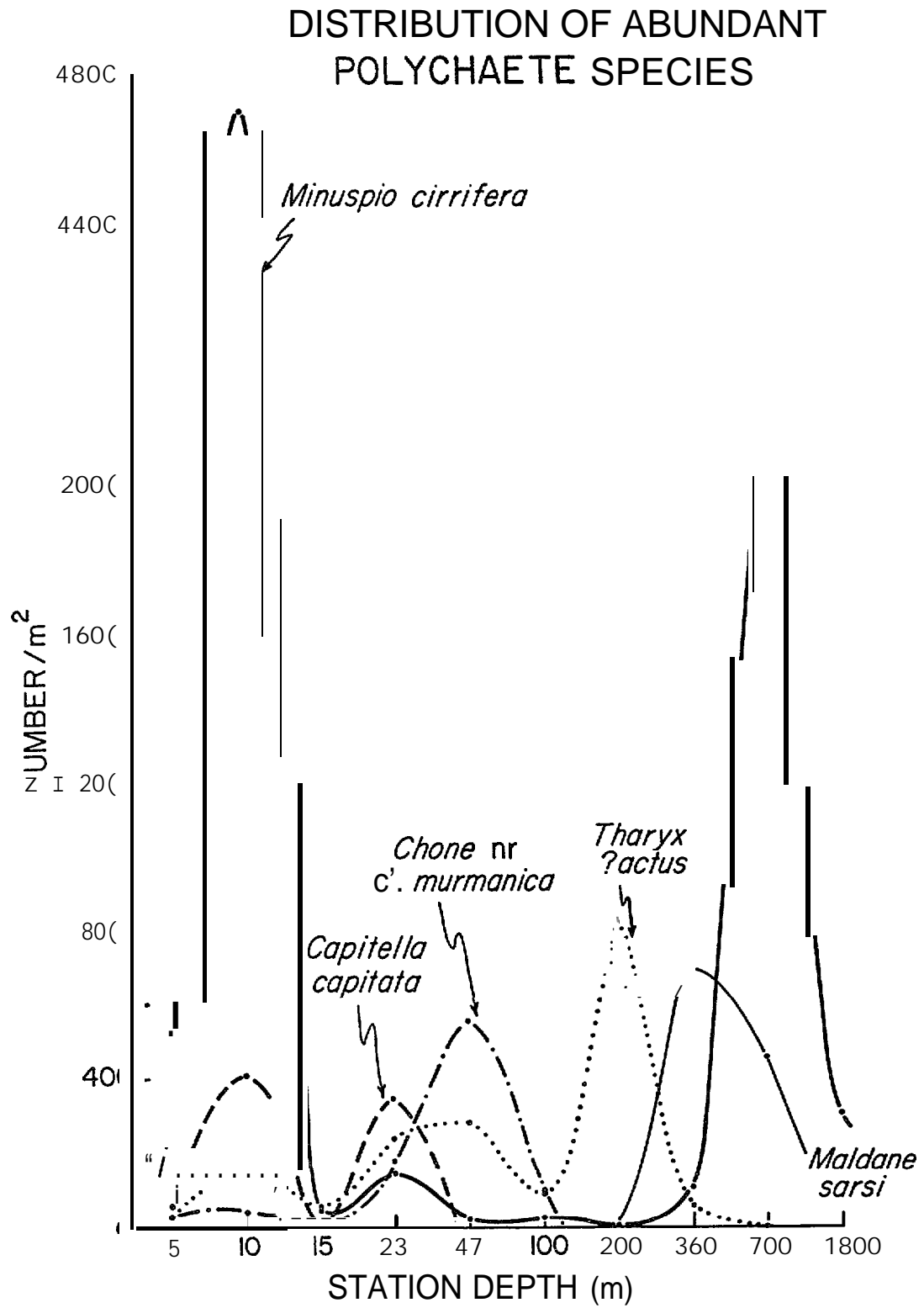


Figure 7. Patterns of distribution and abundance of dominant polychaete species on the Pingok Island cross-shelf transect. Means of 5 samples per station.

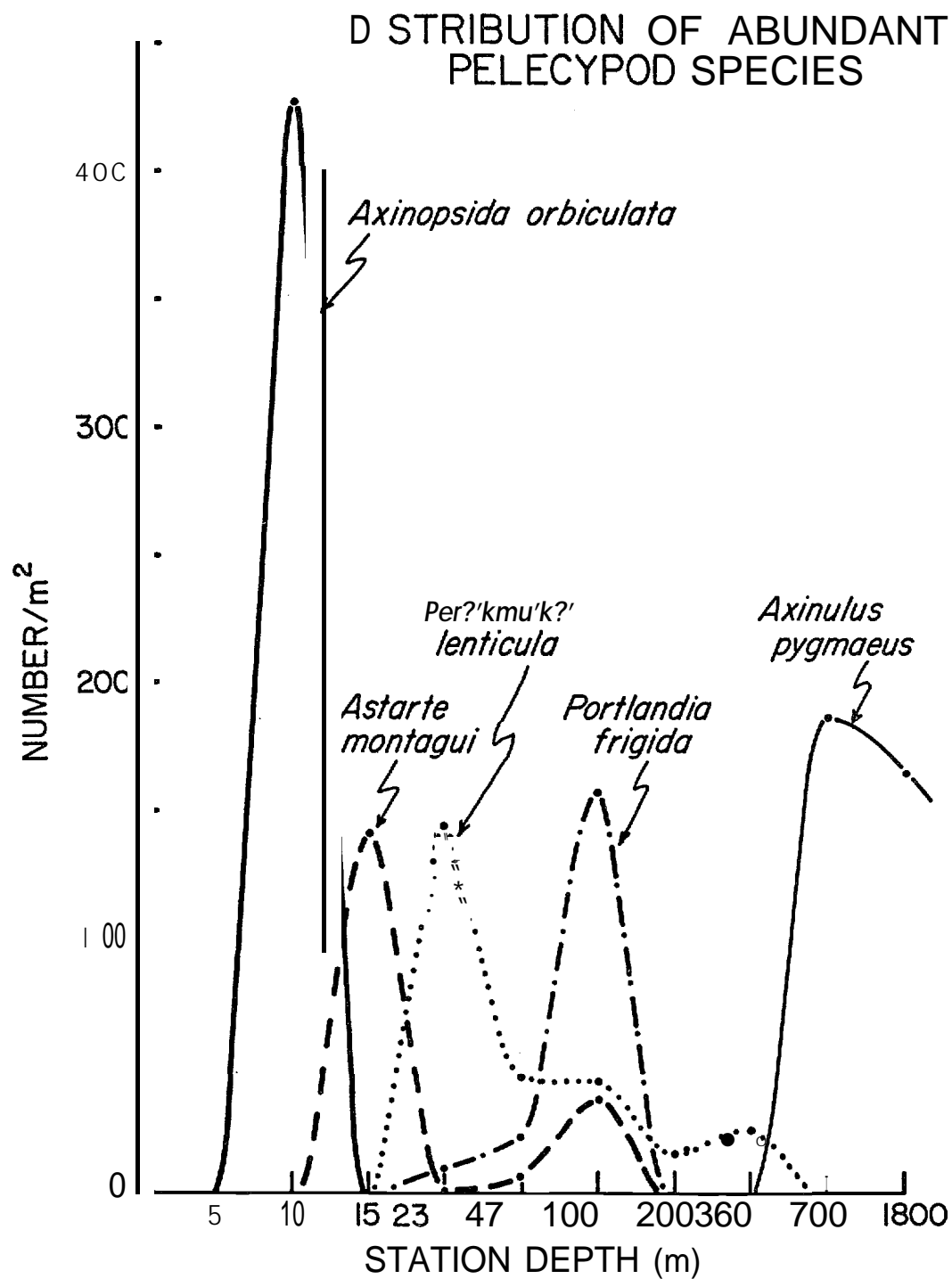


Figure 8. Patterns of distribution and abundance of dominant pelecypod species on the Pingok Island cross-shelf transect. Mean of 5 samples per station.

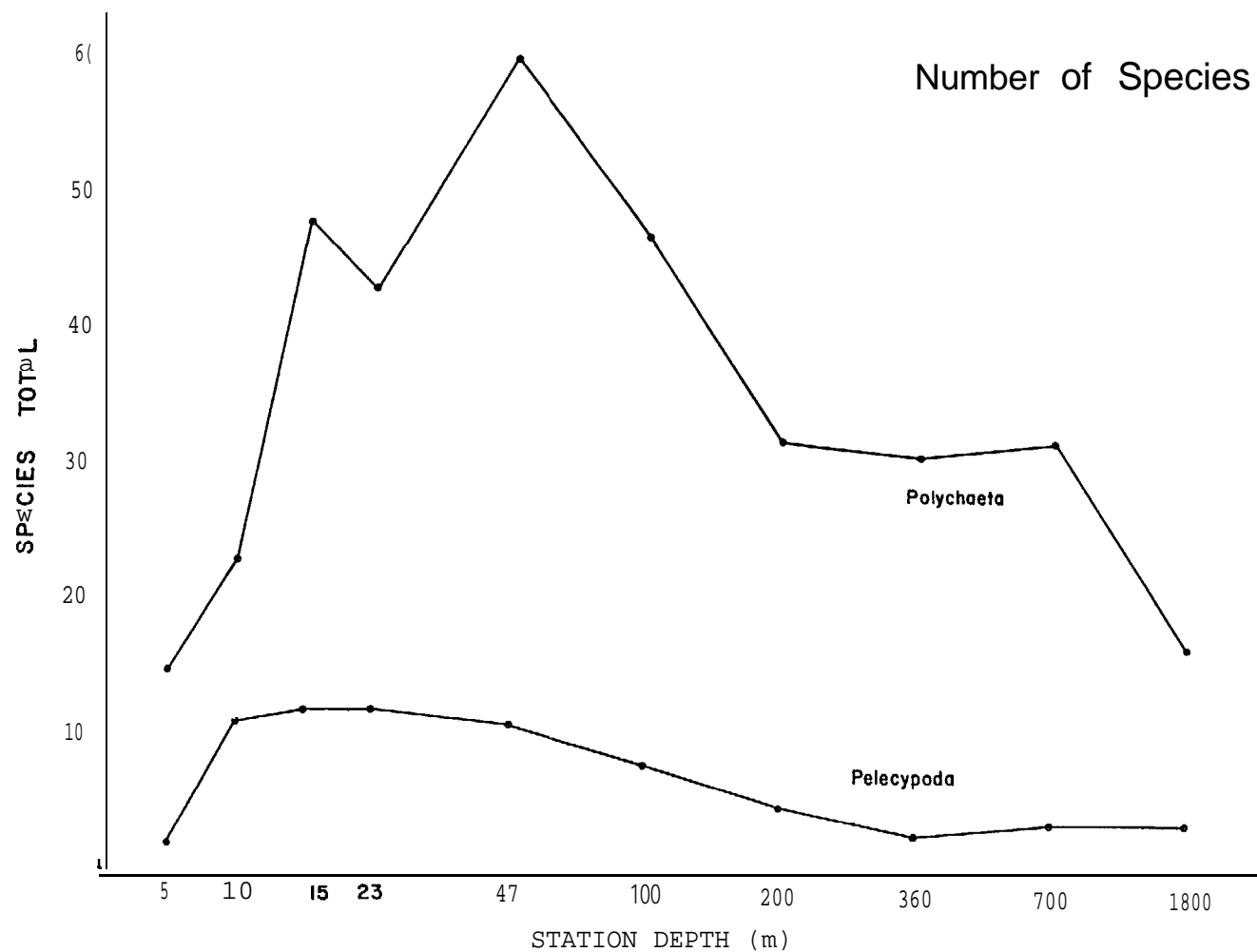


Figure 9. Number of species of Polychaeta (Annelida) and Pelecypoda (Mollusca) on the Pingok Island cross-shelf transect. Total of 5 samples per station.

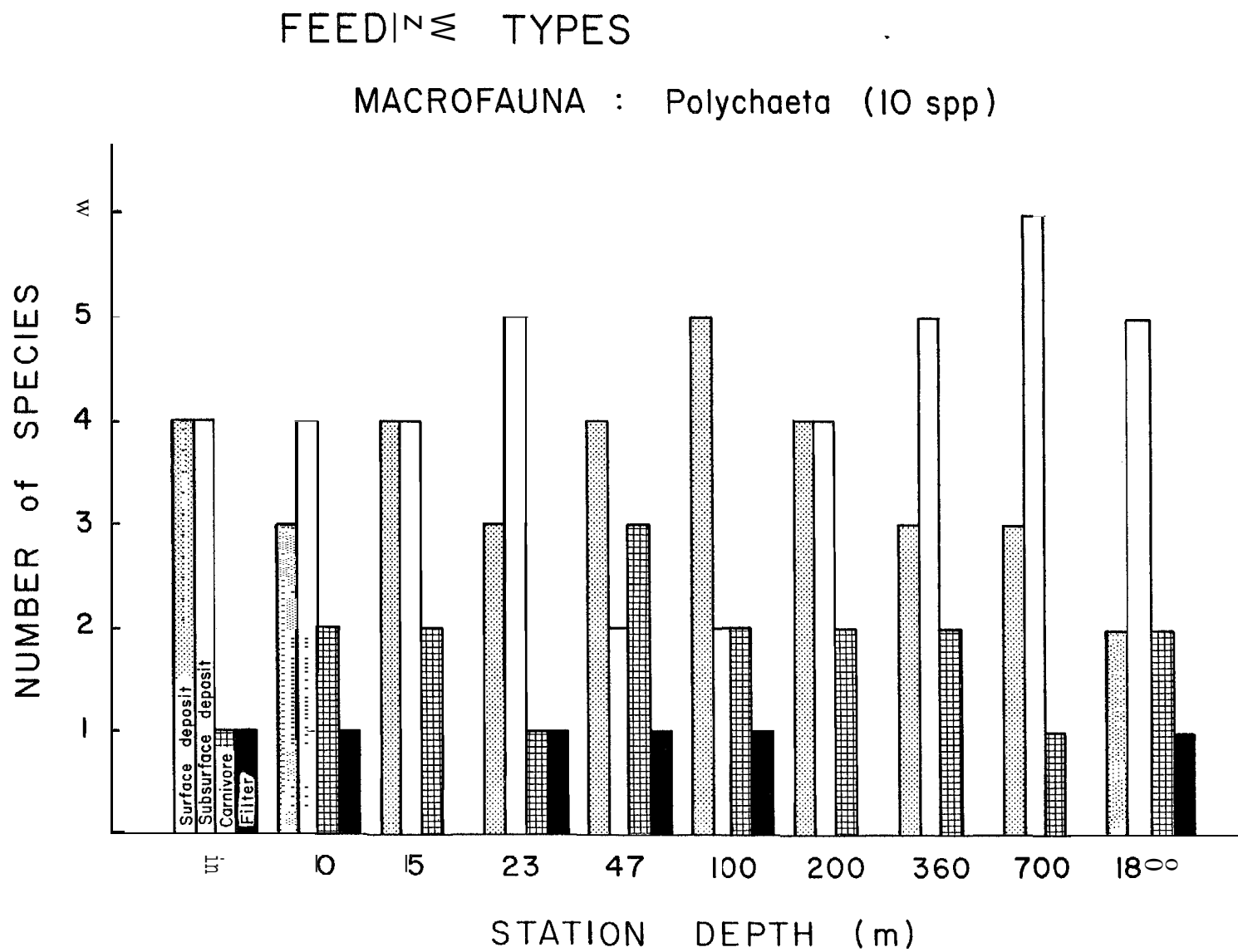


Figure 10. Feeding types of the 10 most abundant polychaete species on the Pingok Island cross-shelf transect.

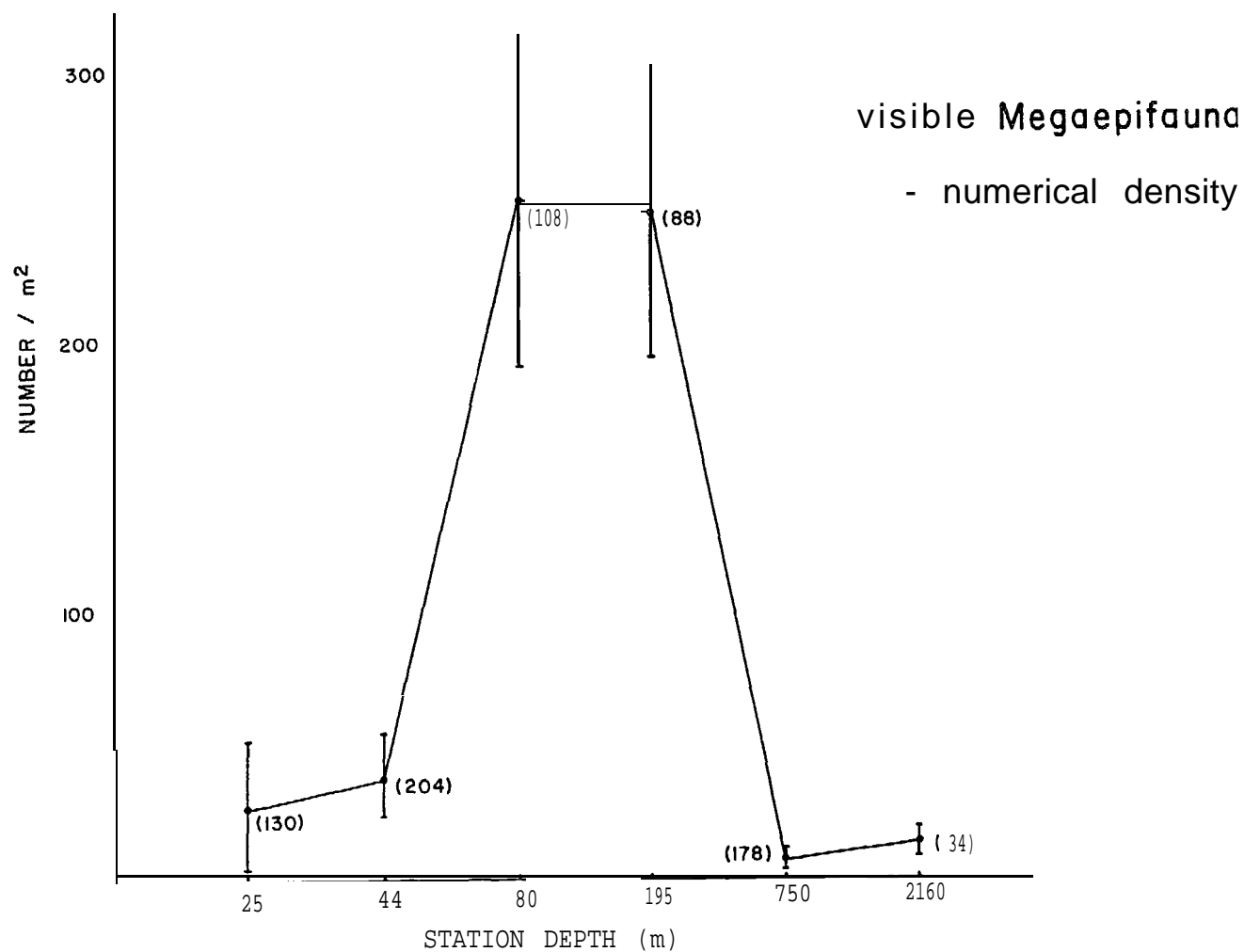


Figure 11. Abundance of visible mega-epifauna (>1.3 cm). Estimates derived from stereo bottom photography. Numbers in parentheses indicate the photographic aerial coverage (m<sup>2</sup>) at each station.



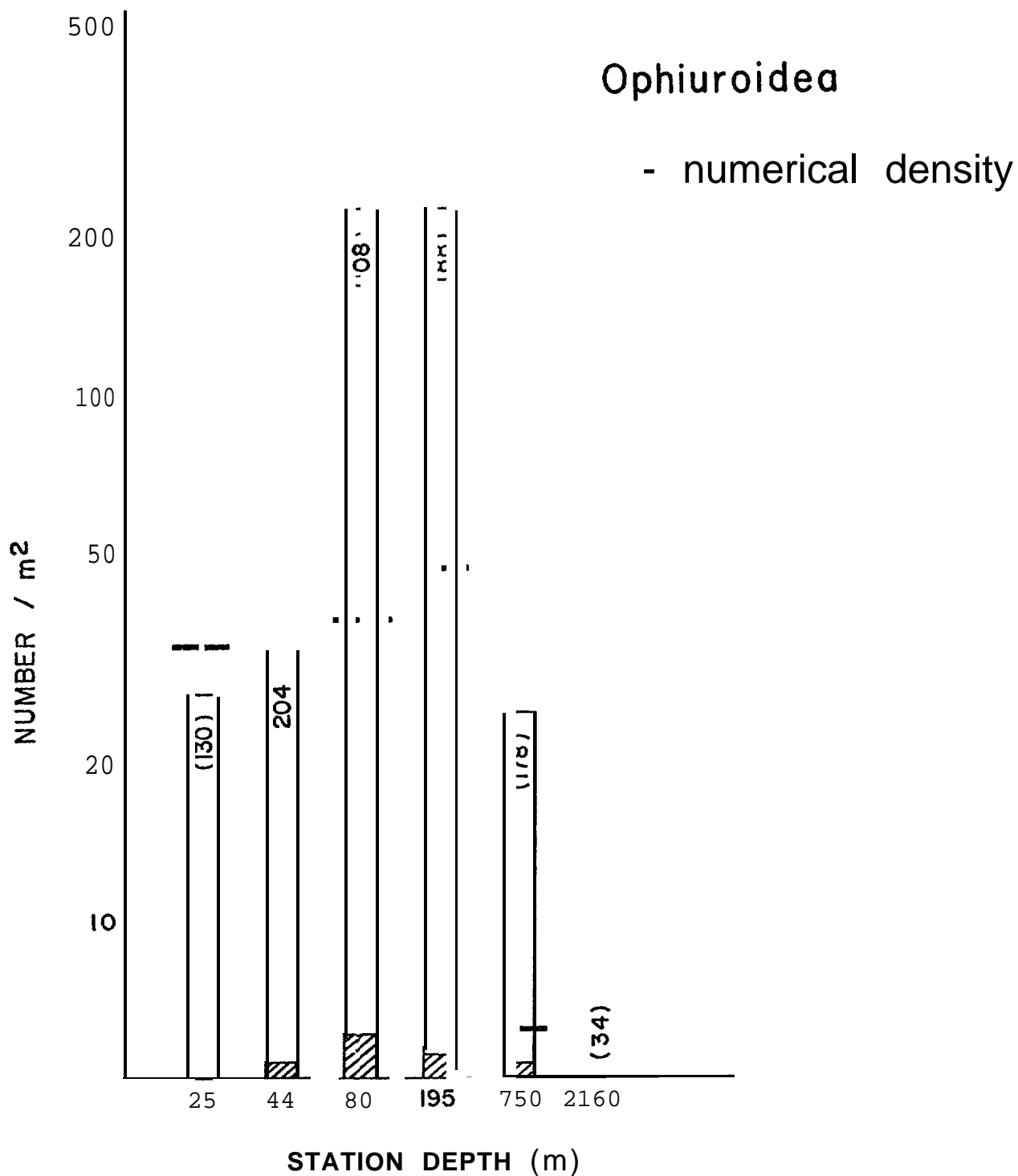


Figure 12.. Numerical density of the total ophiuroid fauna characterized by bottom photography (bars) and from grab-samples (dashes). Numbers in parentheses indicate the photographic aerial coverage (m²) at each station. Grab sample estimates derived from five replicates (0.5 m²) at each station. Shaded areas indicate the ophiuroid species *Ophiacantha bidentata*.

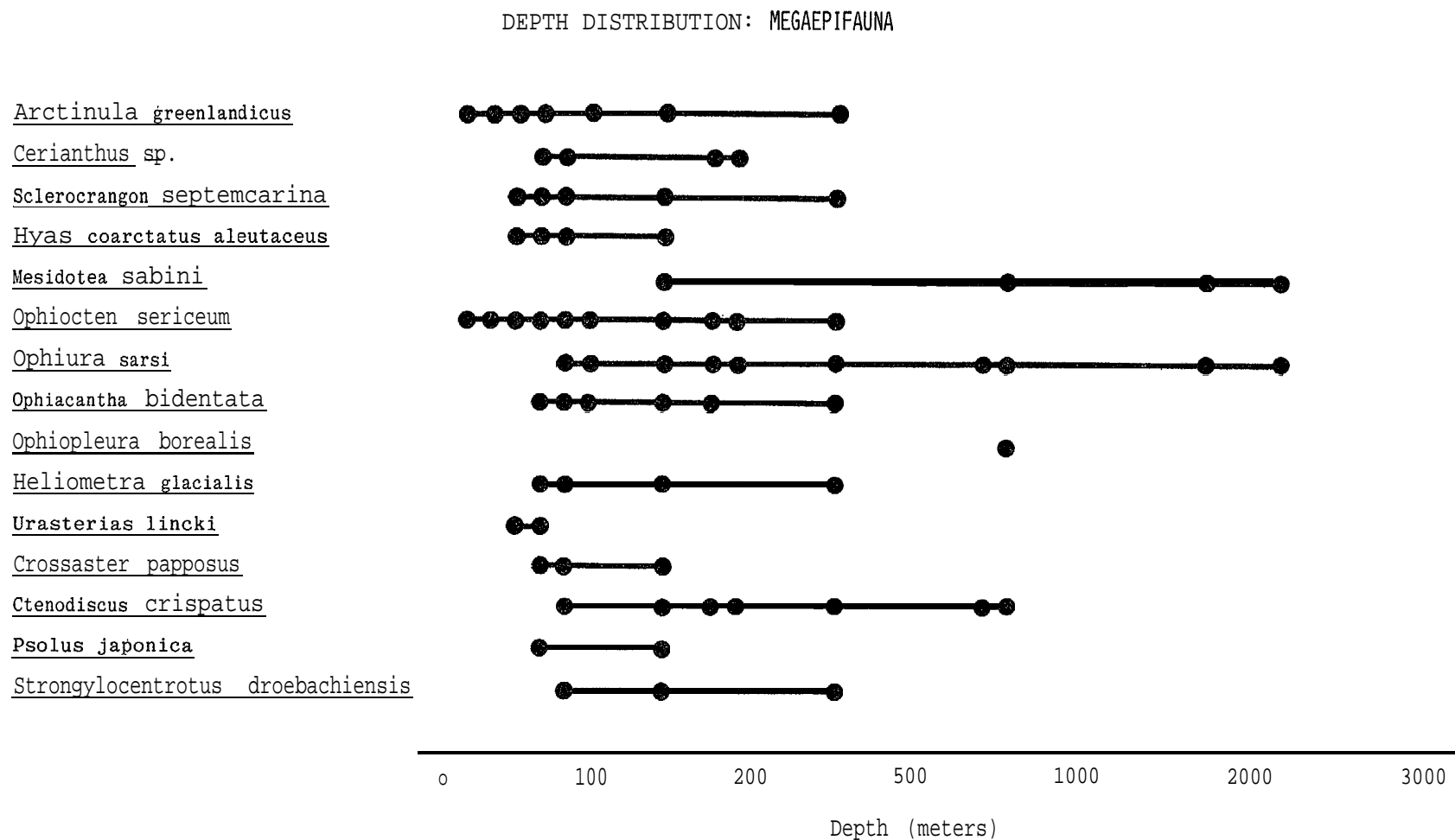


Figure 13. Distributional pattern of mega-epifauna (>1.3 cm) on the Pingok Island cross-shelf transect. Data derived from both otter trawl collections and bottom photography.

## B. Ice fauna (Narwhal Island ice station)

### 1. Ice meiofauna (Kern, 1981)

Nematodes, copepods, turbellarians, polychaetes, and amphipods were collected from the undersurface of the ice. The mean number of individuals collected per 100 cm<sup>2</sup> for each group at all dates when corers were used, with the associated standard deviations, is given in Appendix II: Table 25. Nematodes dominated, comprising 47.0% of the fauna collected throughout the study (Figure 14). Copepods and turbellarians made up 28.8% and 16.1% of the fauna, respectively. Polychaetes and amphipods were minor members of the ice fauna, together representing less than ten percent of the total.

Each group showed a significant change in abundance over time. In general, the number of individuals within each taxon increased as the ice algal bloom progressed. Polychaetes were the only exception to this pattern, with their greatest density occurring on 24 April. Nematode and turbellarian abundance increased rapidly from minimum values at 24 April to maximum on 2 June. Copepods exhibited a different trend in abundance (Figure 15), appearing to decrease initially, then increase, and finally decrease again. Since the standard deviations are high, it is possible that this pattern is not real.

Seven species of cyclopoid and harpacticoid copepods were identified from the ice. The mean number of individuals collected per 100 cm<sup>2</sup> for each of the five dominant species, and the associated standard deviation, is given for each date on which cores were taken (Appendix II: Table 26). Cyclopina gracilis, a cyclopoid, was the dominant species, making up 55.0% of the ice copepod fauna. Harpacticus sp. and Halectinosoma sp., two harpacticoids, comprised 23.0% and 19.8% of the copepods, respectively. The cyclopoid Oncaea sp. represented 1.5% of all copepods and Dactylopodia signata, a harpacticoid, less than one percent. Two copepodites were collected that probably belonged to the species Cyclopina schneideri. The seventh species was represented by a single individual that was too young to identify.

Although there was a significant change in abundance over time for total copepods, densities of two species, Halectinosoma sp. and Dactylopodia signata, did not change significantly. The abundance of Cyclopina gracilis and Harpacticus sp. did change significantly through the study ( $P < .002$ ), as well as that of Oncaea sp. ( $P < .05$ ). The three dominant species displayed similar patterns in abundance over time (Figure 15). Densities appeared to decrease initially, reach a maximum in the second half of May, and then decrease toward the end of the study.

Data on the life-history characteristics recorded for the two dominant copepods, Cyclopina gracilis and Harpacticus sp., are given in Appendix II: Table 27. Cyclopina gracilis adults were present at all dates. Only copepodites of Harpacticus sp. were collected before 11 May. Harpacticus sp. males were more abundant than females until the final three sampling dates. The reverse trend occurred with C. gracilis where females outnumbered males initially, but were generally less numerous after 5 May. Gravid C. gracilis females were collected on five of the sampling dates, but were never a large percentage of the adult female population. No gravid Harpacticus sp. females were found in the ice, but pre-copulatory clasping pairs were present on 26 May and 2 June. Adult males clasped late copepodite females on the prosome with their modified antennules.

The size-frequency distribution of Harpacticus sp. indicates that the population structure changed greatly during the course of the study (Figure 16). Over 95% of the Harpacticus sp. individuals could be measured. Initially the population was composed entirely of copepodites. By 15 May, however, a mode appeared at approximately 840 microns that was composed of adult males and late copepodite females. This feature remained in later samples because the adult males had reached their maximum size. Females continued to grow and a broad mode corresponding to adult females was seen beginning 19 May. Significant differences in population

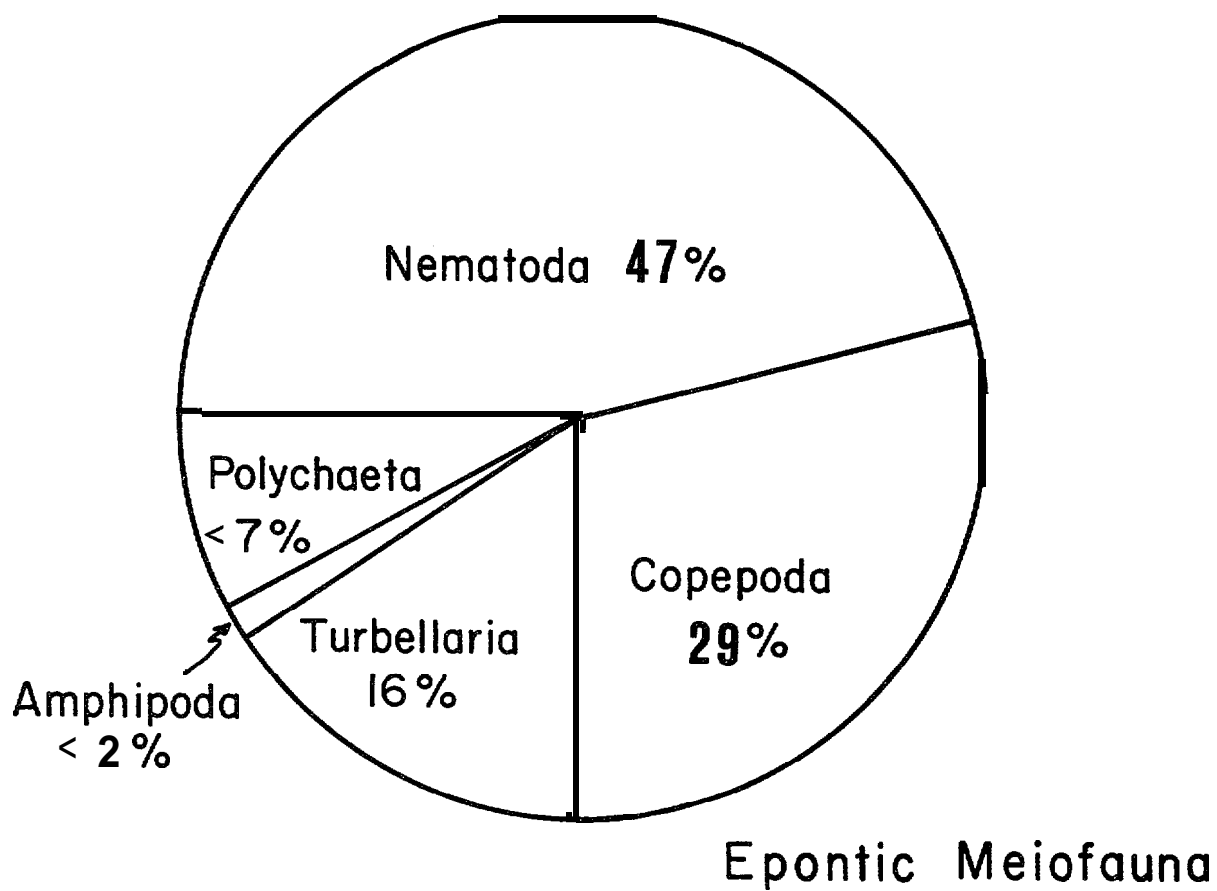


Figure 14. Composition of sea ice meiofauna by major taxa at the Narwhal Island ice station, spring, 1980.

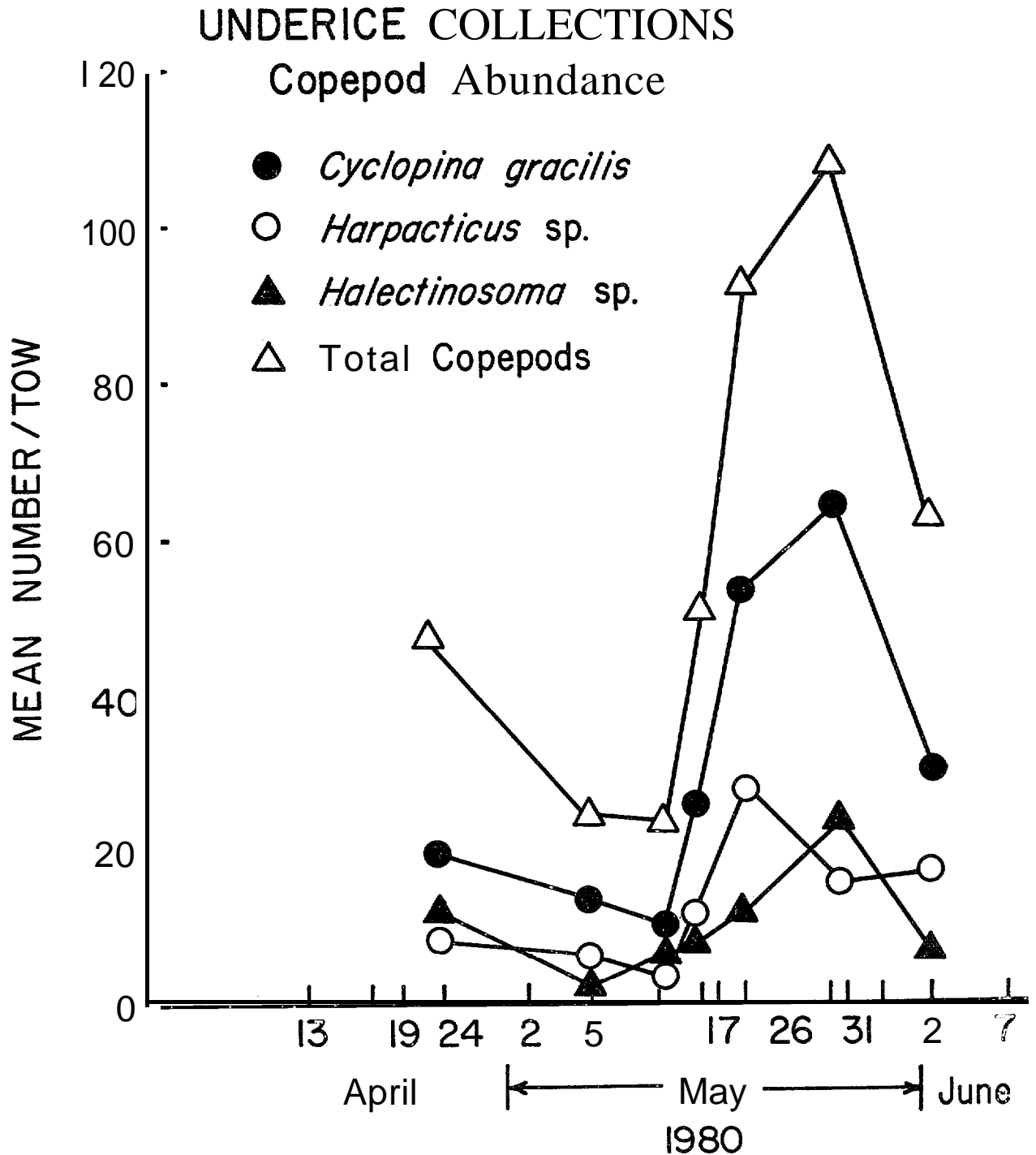


Figure 15. Abundance of underice copepods during the spring, 1980, at the Narwhal Island ice station.

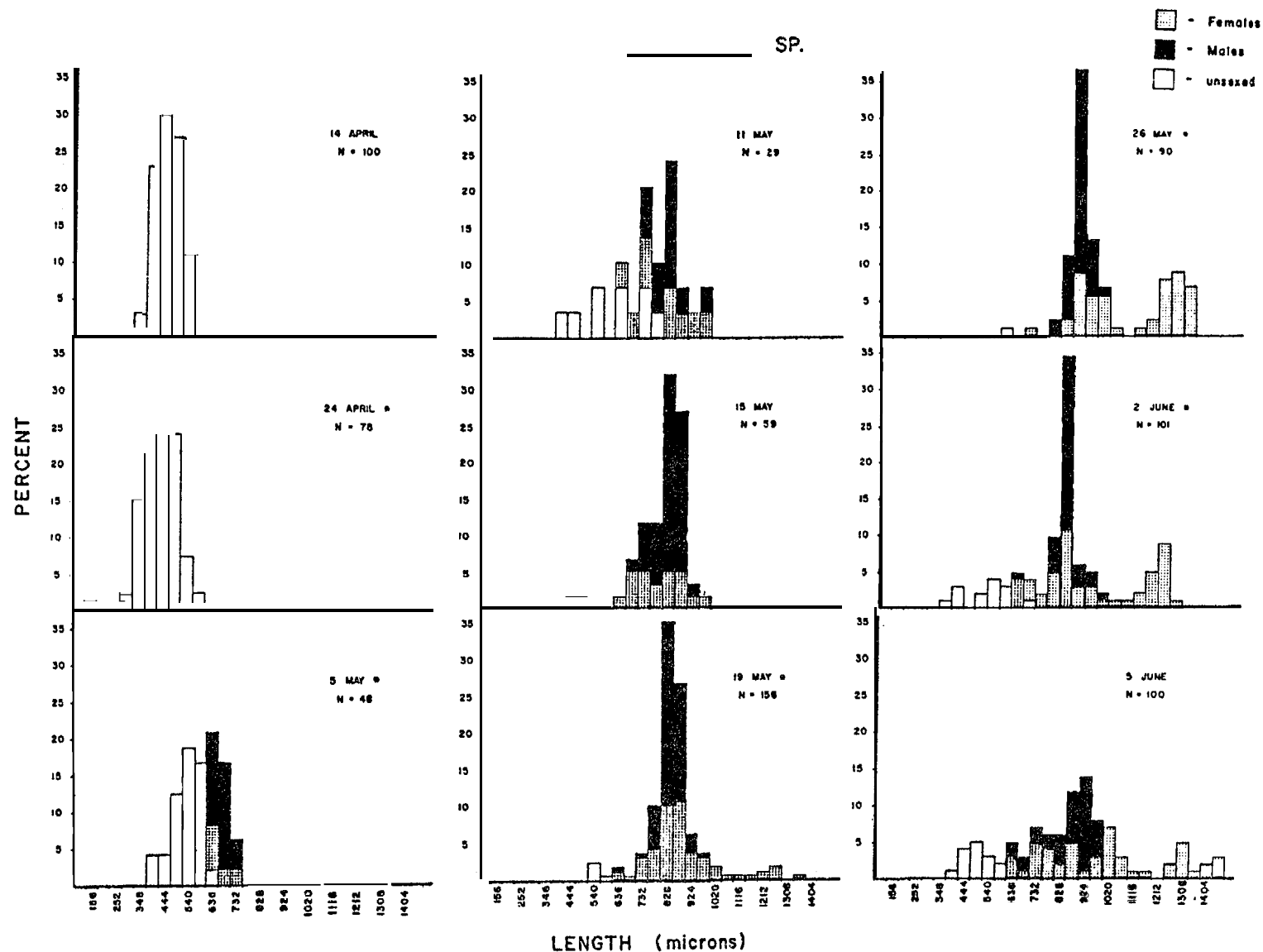


Figure 16. Size-frequency distribution of Harpacticus sp. collected from the underice surface during the spring, 1980, at the Narwhal Island ice station.

structure were indicated by the Kolmogorov-Smirnov test in the second and third comparisons (24 May-26 May, 26 May-2 June, and 2 June-5 June). Only 29 individuals were measured from 5 May and this sample size is inadequate to calculate the test statistic where the sample sizes are unequal (Tate and Clelland, 1957). To make comparisons between this date and the preceding and following sampling dates, the smaller sample size was used alone to determine the test statistic.

The population structure of Cyclopina gracilis (Figure 17) changed greatly during the study, but most of the change occurred in the early samples. Over 92% of all individuals could be measured. The Kolmogorov-Smirnov test indicates that significant changes in the size-frequency structure of the population occurred between the first two sampling dates (14 April-24 April), the second and third dates (24 April-5 May), the fifth and sixth dates (15 May-19 May), and the eighth and ninth dates (2 June-5 June). The earliest samples contained mostly juveniles. In the cores taken 15 May, and in all following samples, three major modes were evident in the size-frequency distributions. The first mode, centered at around 260 microns, was composed of young copepodites. The second, located at approximately 520 microns, was largely made up of adult males and late female copepodites. Adult females had a much greater size range than males, and had a broad peak centered near 700 microns. The size-frequency distributions of C. gracilis on 5 June had these three modes, but they were broader and had shifted to larger sizes relative to the previous dates.

Data from the time-series midwater collections with the 0.75 m ring net demonstrate that harpacticoid copepods are present in the water column only at the end of the season (Figure 18). At the end of May and early June the harpacticoids appear in the collections and increase in abundance up to the very end of the study.

## 2. Ice macrofauna - sources and seasonal trends

The epontic macrofauna (>0.5 mm) is predominantly comprised of gammarid amphipods. A mean of 99.3% of the macrofauna caught on the ice undersurface with the SCUBA diver-operated ice net sampler were amphipods (Figure 19). The remaining 0.7% of the sea ice macrofauna were miscellaneous arthropods, cnidarians, and polychaetes.

The gammarid amphipods are the dominant taxonomic group associated with the sediments in the study area. A mean of 53.5% of the macro-epifaunal organisms were amphipods while arthropods, i.e., cumaceans, mysids and ostracods represented 45.2% of the fauna captured by the standardized net tows, and miscellaneous species, i.e., nemerteans, annelids and molluscs made up the remaining 1.3% of the epifauna.

During the latter part of the study period there is a significant increase in the number of amphipods per unit area at the ice-water interface (Figure 20), increasing from  $25 \text{ m}^{-2}$  to  $340 \text{ m}^{-2}$  ( $p = <.005$ , Kruskal-Wallis rank analysis). The increase in numerical abundance is caused by juvenile amphipods released from adult female broad pouches at the ice undersurface in early June during the ice melting period (Figure 21). To a large degree the adult Pseudalibrotus litoralis and their offspring form most of the ice assemblage. Therefore, it is not surprising that the pattern of the release of P. litoralis juveniles is the same as for the total amphipod fauna on the ice undersurface ( $P = <.005$ , Kruskal-Wallis rank analysis). In contrast, the number of gammarids associated with the sediment remained low throughout the total study period (Figure 22). At the end of the spring season the benthic P. litoralis population was 2% of ice population off Narwhal Island.

Excluding juveniles the benthic Pseudalibrotus litoralis population was 6% of the ice faunal abundance. However, additional data from an unpublished report demonstrates that during the latter part of the summer P. litoralis is abundant on the inner Beaufort Sea continental shelf (Carey, 1981). During August 1976, there were 24 individuals per  $\text{m}^2$  at 10 m depth, 294 at 15 m and 16 at 20 m.

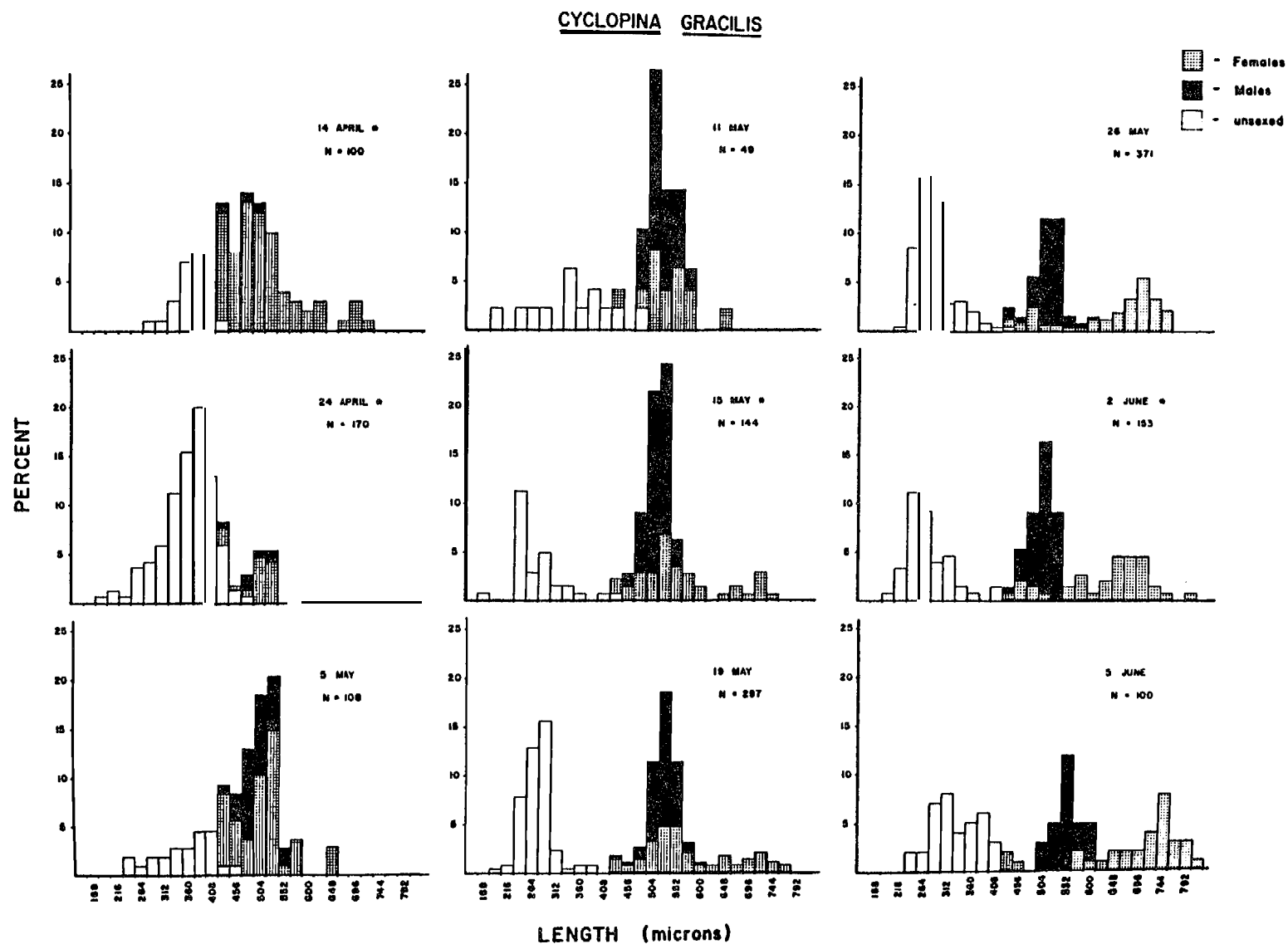


Figure 17. Size-frequency distribution of *Cyclopina gracilis* collected from the underice surface during the spring, 1980, at the Narwhal Island ice station.



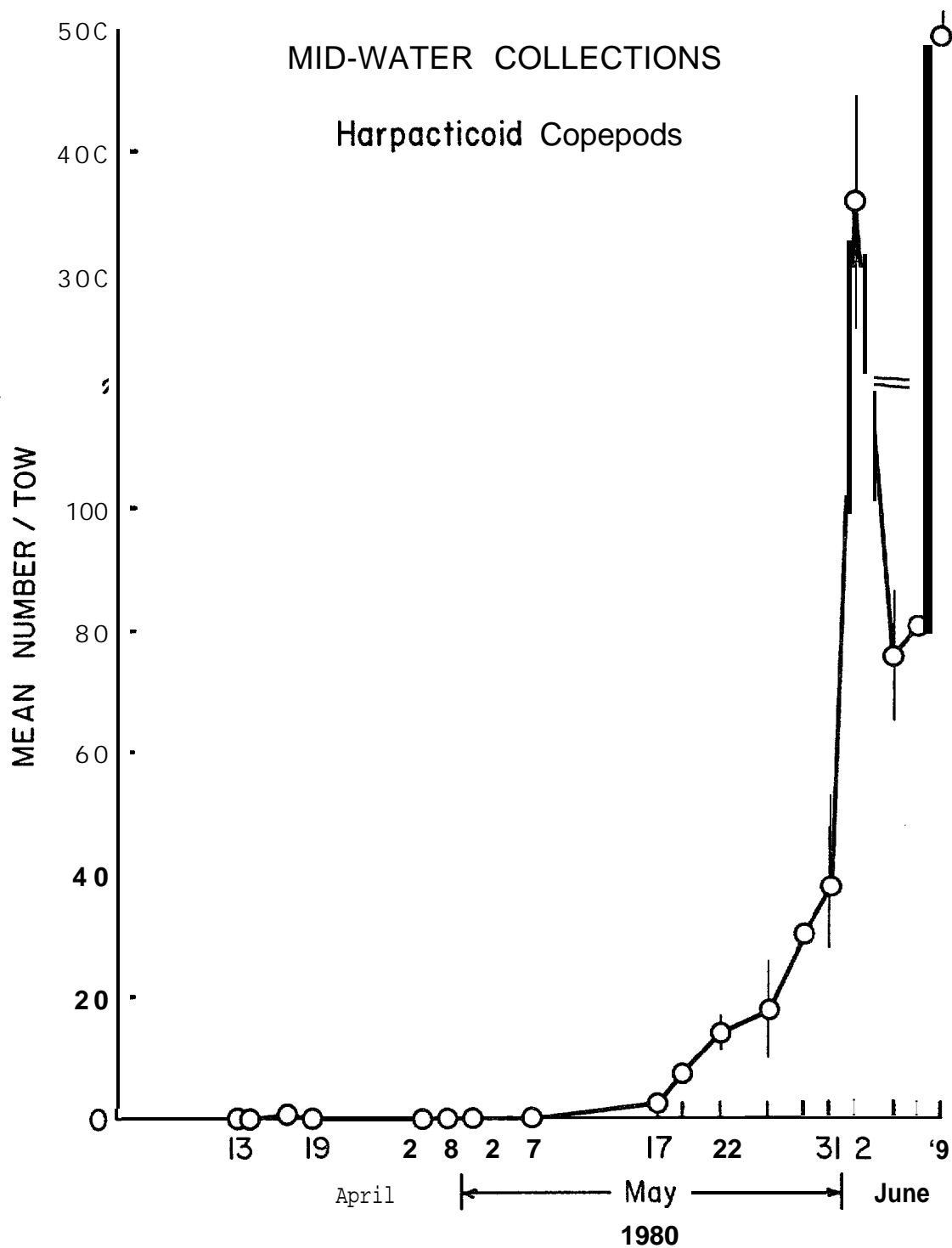


Figure 18. Mid-water collections of harpacticoid copepods by 3/4 meter ring net at Narwhal Island ice station, spring 1980. The mean and total range is indicated for the sample pairs.

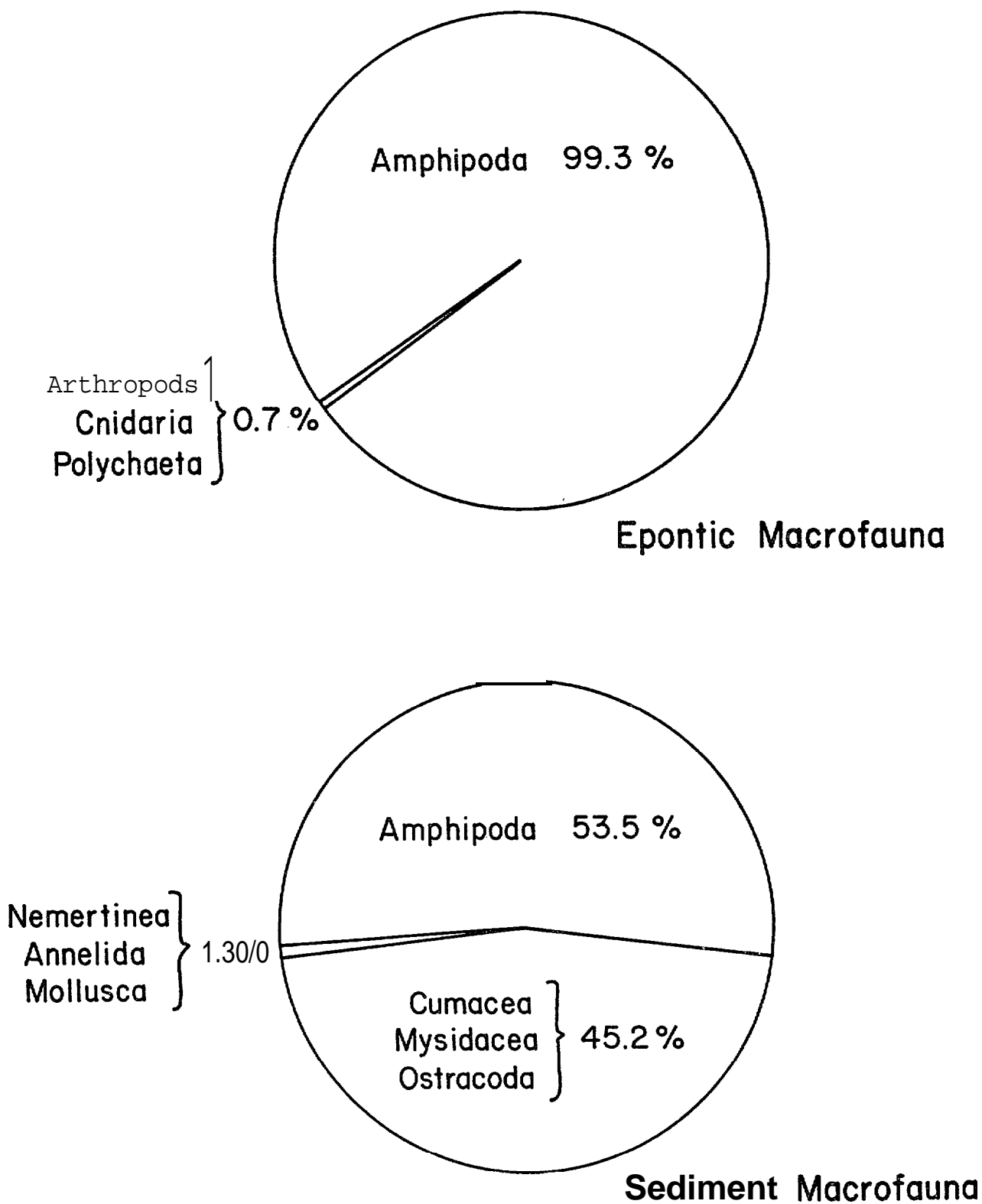


Figure 19. Comparison of major taxonomic composition of ice (epontic) macrofauna and benthic macrofauna at the Narwhal ice station, spring, 1980.

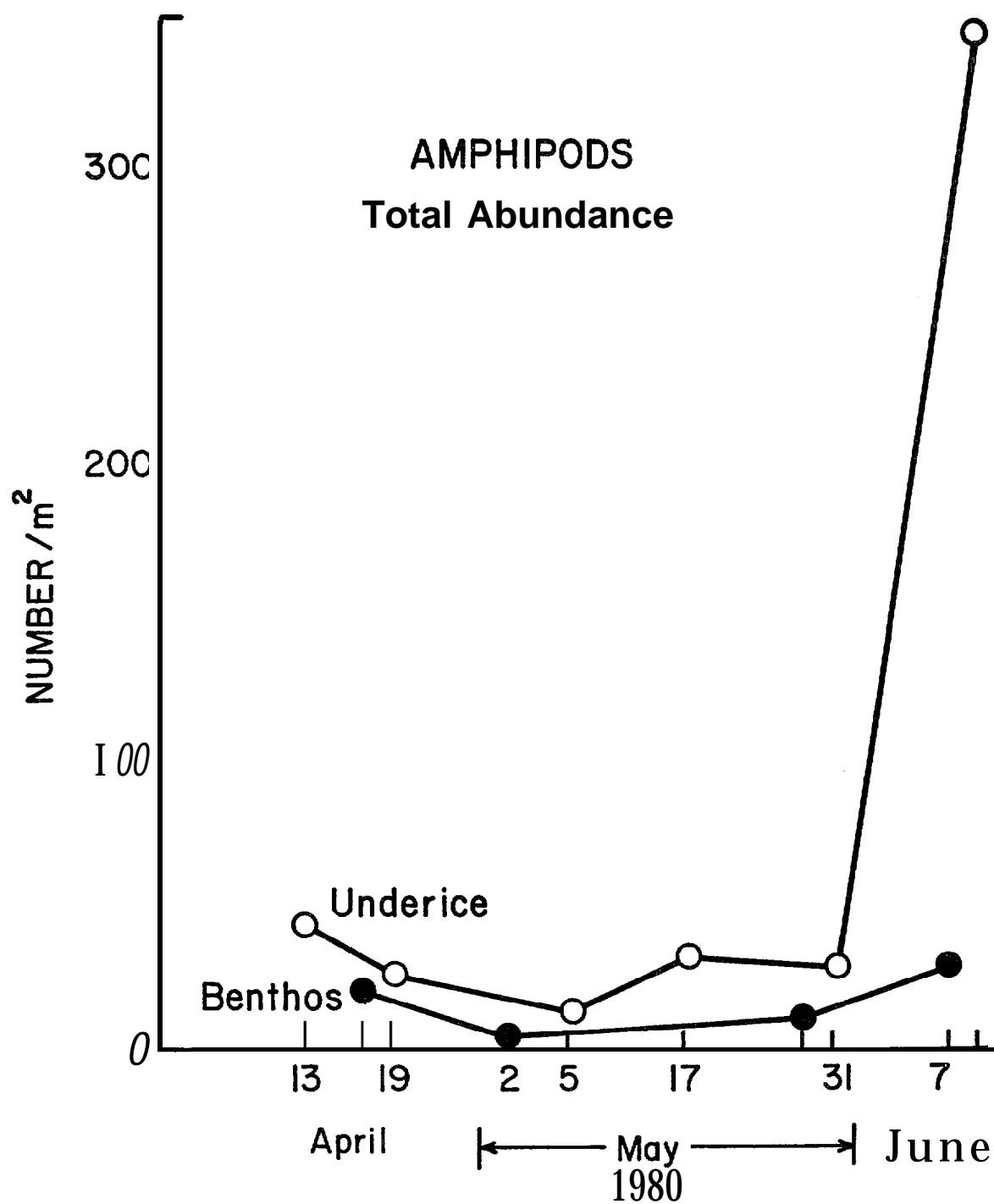


Figure 20. Comparison of the abundance of amphipods on the ice undersurface and the sediment surface at the Narwhal Island ice station, spring 1980.

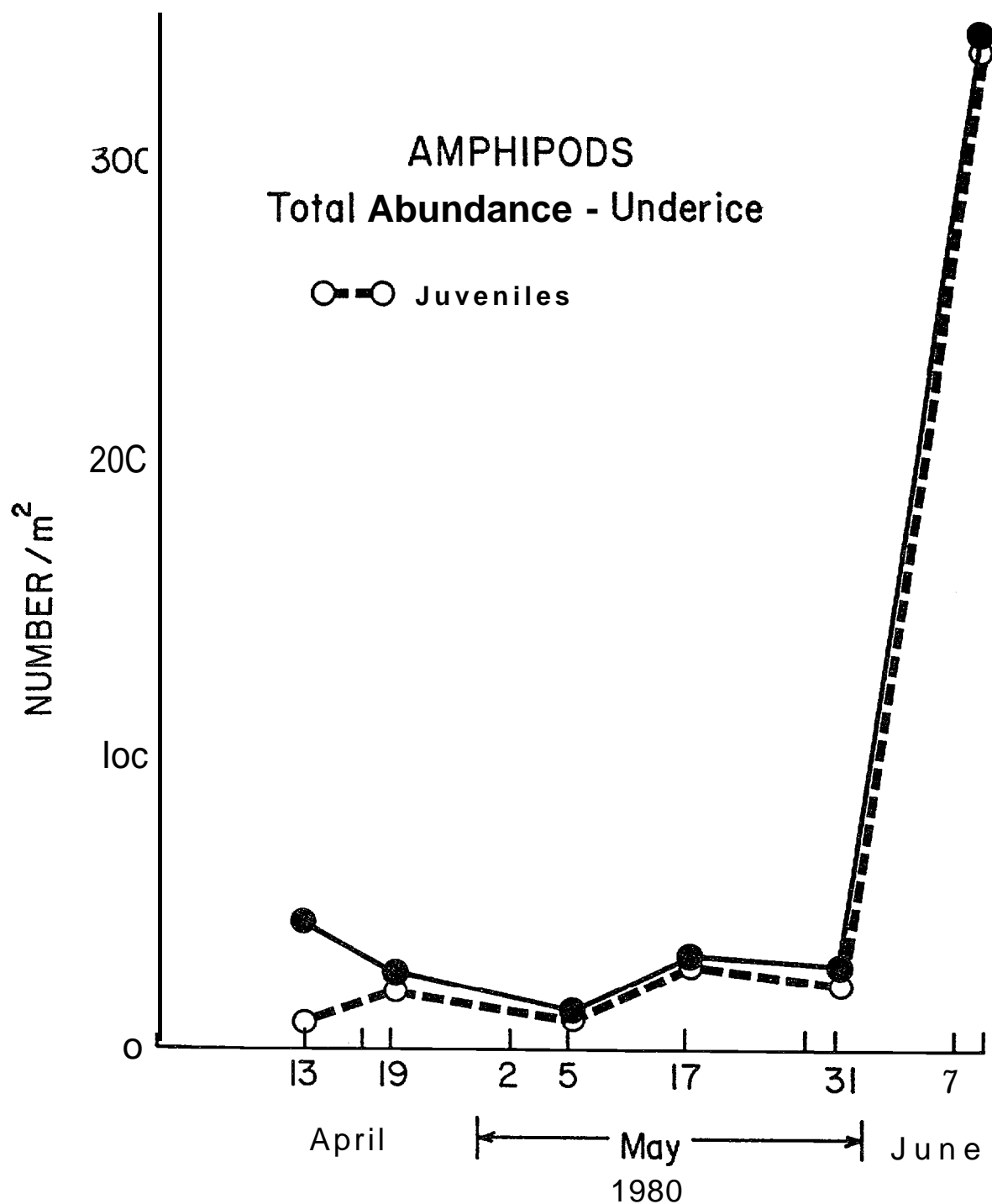


Figure 21. Abundance of underice gammarid amphipods at the Narwhal Island ice station, spring 1980. Note the predominance of juveniles and the major recruitment in early June.

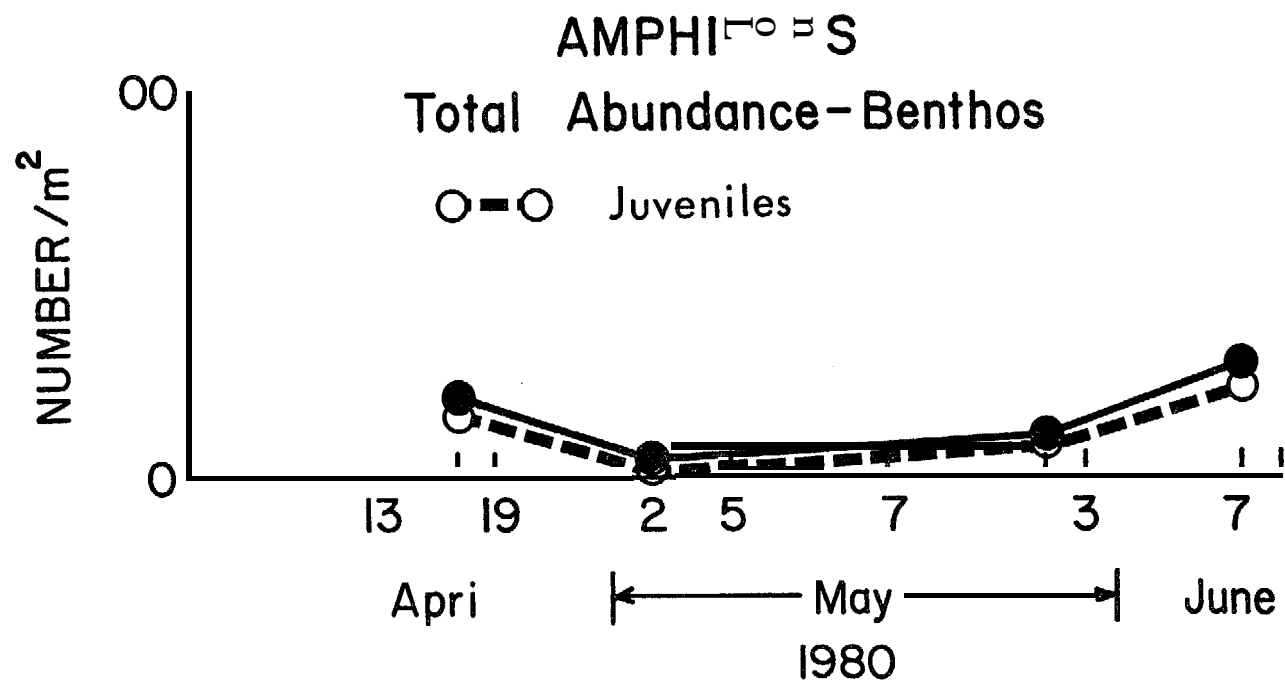


Figure 22. Abundance of benthic gammarid amphipods at the Narwhal s and ice station, spring 1980. Note the predominance of juveniles.

Five species of gammarid amphipods were collected from the ice undersurface, nine from the water column and thirteen from the sediments (Appendix 11: Table 28). Though Pseudalibrotus litoralis dominates the amphipod ice assemblage with a mean of 9.1 per m<sup>2</sup>, it is also found as the numerically important member of the water column and sediment macrofaunal assemblages. Because P. litoralis is the only species dominant in all three environments, its affinities are widespread during the ice-covered months on the Beaufort Sea shallow continental shelf (Figure 23). The affinities of the abundant species can be assigned to one or two of the environments. Four species, i.e., Onisimus affinis, Onisimus plautus, Acanthostepheia malmgreni and Onisimus cf. aderjugini were found only associated with the bottom. Weyprechtia pingius came from only the ice and water column, and the five ice species were all collected from other environments in addition.

The relationship of the ice, water and sediment populations of Pseudalibrotus litoralis was studied by sampling all three environments during the spring study period. The midwater collections demonstrate that some P. litoralis were present in the water column at all times during the spring (Figure 24), though during April there were more individuals caught mid-water in the early morning hours (Figure 25). As the sun-lit day length increased during the spring this tendency weakened and disappeared. At the end of the season before ice break-up there appears to be a tendency for maximal activity in the water column also during the early morning hours. Perhaps the decreasing salinity at the ice-water interface (Figure 26) coupled with the dim morning light entrain the movement of the amphipod away from the ice. Though these data indicate the seasonal and diurnal activity of P. litoralis in the water column, they do not prove vertical migrations between the ice and the sediments per se. Because of the patterns observed it is likely, however, that the movement of the amphipod between the two surfaces is fairly continuous during the spring.

The population characteristics of Pseudalibrotus litoralis change throughout the season at the underice surface (Figures 27 through 32) (Boudrias and Carey, unpublished). The mean length of the adults demonstrates a general trend of growth from April through early June, 1980 (Figures 33 through 35). Though each data point does not represent a significant change in size from one sampling date to the next, the overall trend appears real. In addition, the mean weights of P. litoralis adults and immatures also tend to increase during the season (Figures 36 and 37). Again, the individual data points are not significantly different from the others, but the overall trends seem real. Part of the variability of these data is caused by continual recruitment of juveniles into the ice populations of P. litoralis (Figure 38). The length-frequency structure of the ice population demonstrates the appearance of young at the ice undersurface throughout the spring.

### C. Particle flux to sediments (Narwhal Island)

The overall result of the organic flux studies at the Narwhal Island Ice Station during the Sea Ice-80 project is that the particle flux is relatively high throughout the entire period. There is no significant temporal variability in the total flux of mass, nitrogen, or carbon (Figures 39 through 41, and Appendix III: Tables 30 through 37). The total particle flux by weight is as high at the initial stages of the development of the ice biotic community as it is at the end in early June, 1980. The collections on May 3 and 11 are highly variable with larger mean mass and may be affected by large, rare particles such as crustacean molts and large fecal pellets (Figure 39). The organic carbon and nitrogen flux under the sea ice also exhibit no significant trends with time. In fact, the striking result, particularly for carbon is that the flux starts, remains and ends at relatively high levels.

A few particle types were distinctive and could be identified and the source determined. These included fecal pellets and crustacean molts. Much of the mate-

## Mid-water Amphipod Affinities

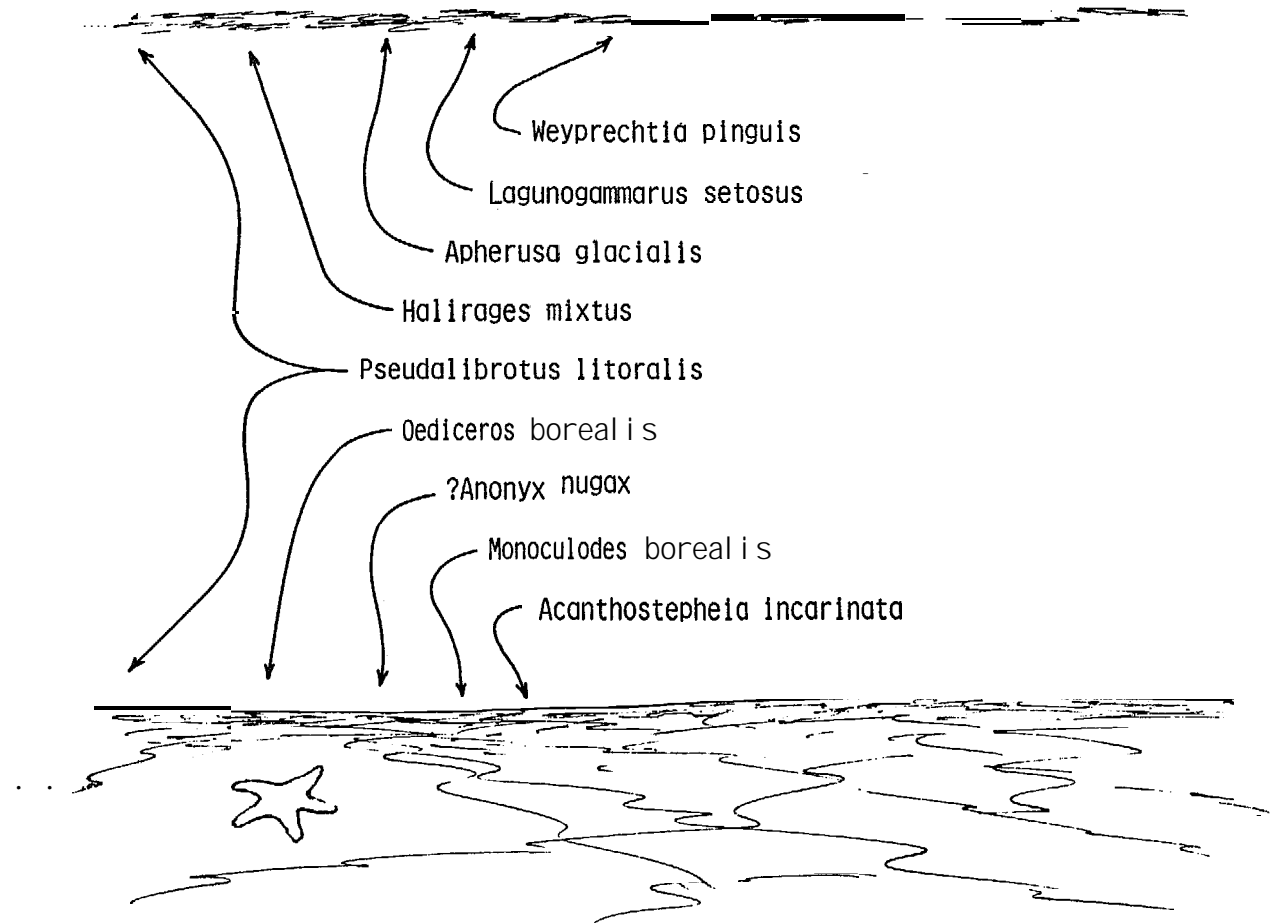


Figure 23. Affinities of gammarid amphipod species in the shallow Beaufort Sea. *Pseudalibrotus litoralis* is abundant in the underice, mid-water, and benthic environments.

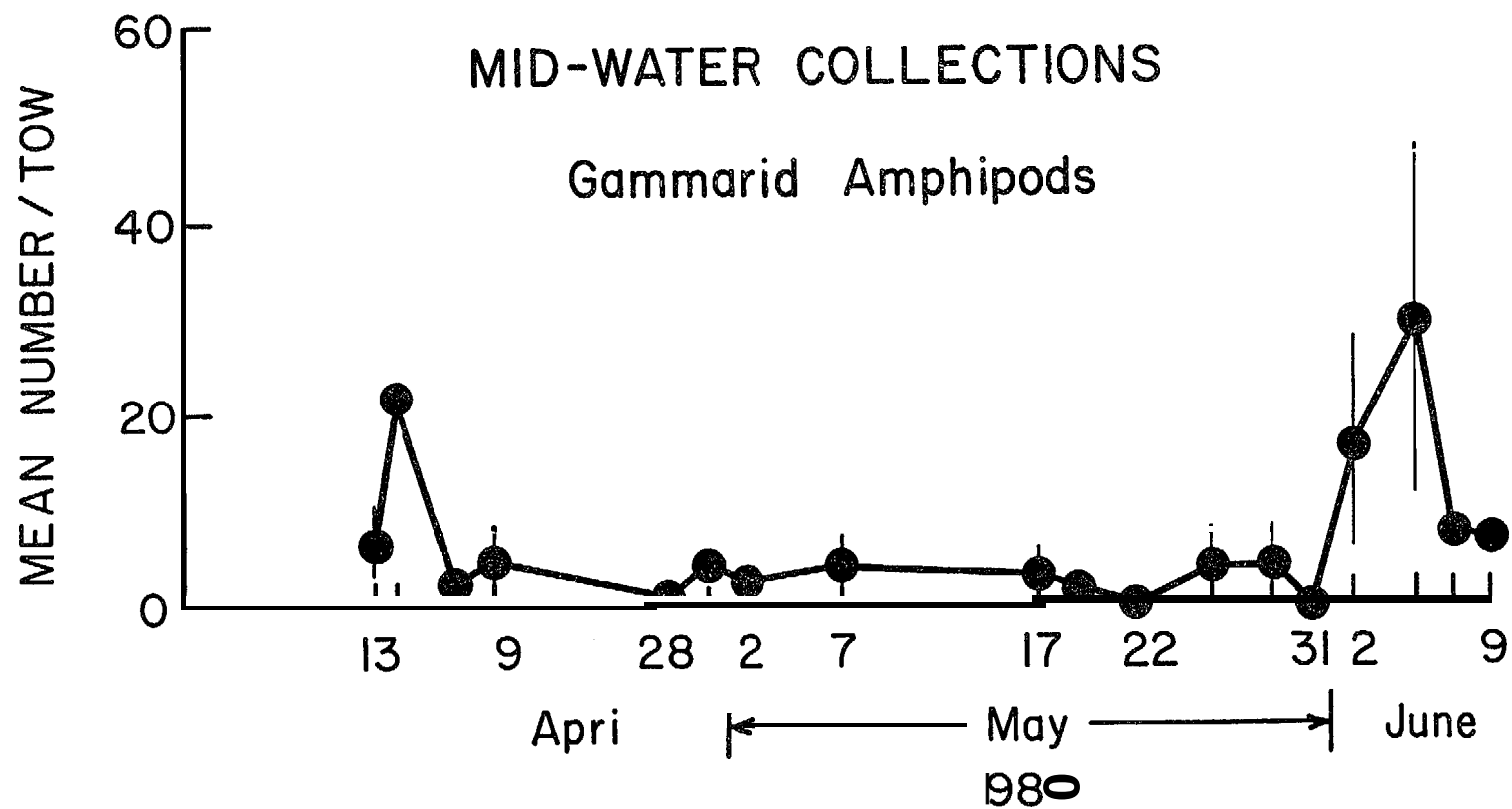


Figure 24. Mean abundance of gammarid amphipods collected by 3/4 meter ring net during the spring, 1980 at the Narwhal Island ice station. Collections made between 1000 and 1200 hrs. The samples were dominated by the amphipod species Pseudalibrotus litoralis.



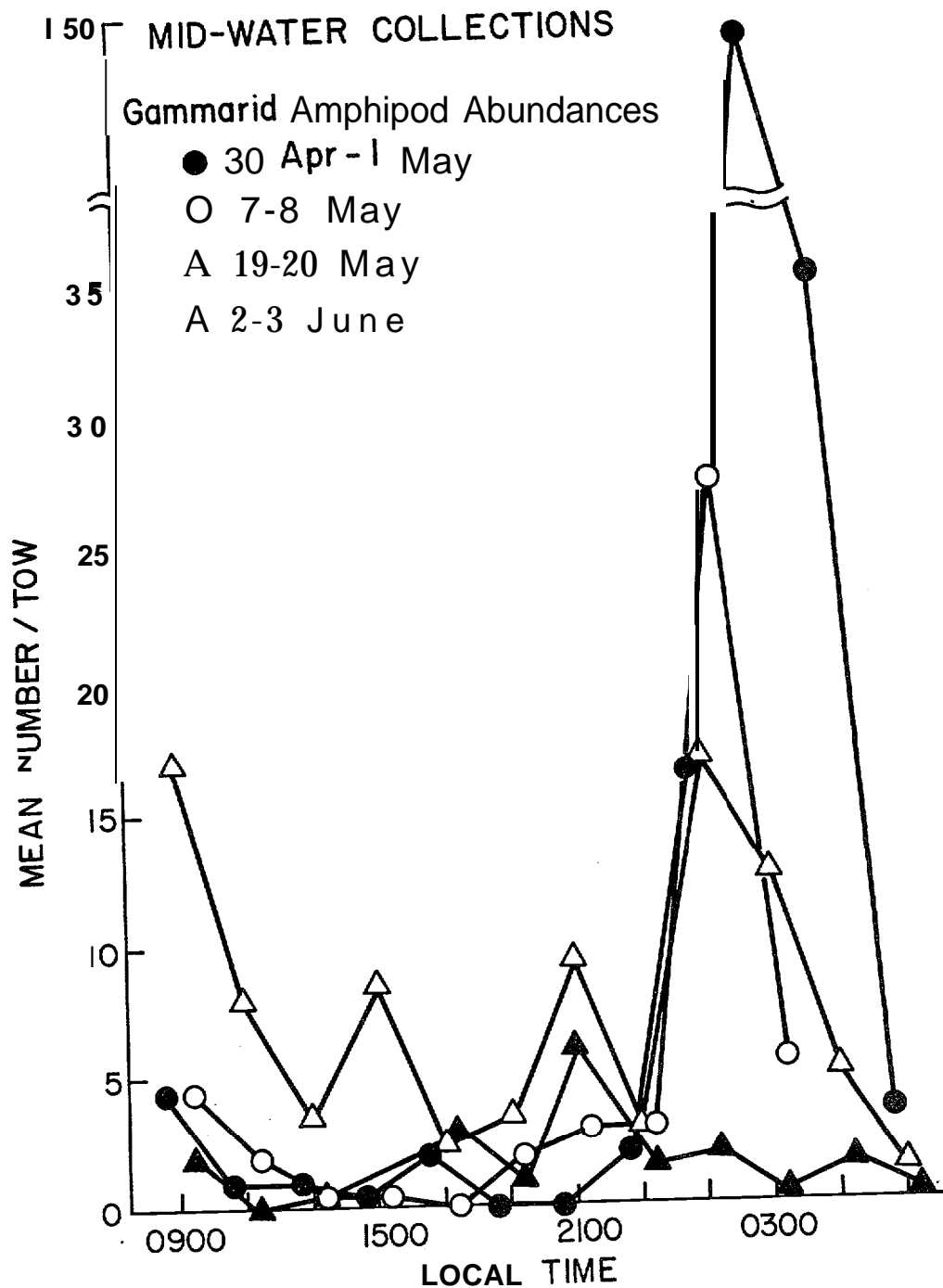


Figure 25. Mean abundance of gammarid amphipods per 3/4 meter net haul during 24 hrs. throughout the spring (1980) at the Narwhal Island ice station. The samples were dominated by the amphipod species Pseudalibrotus litoralis.

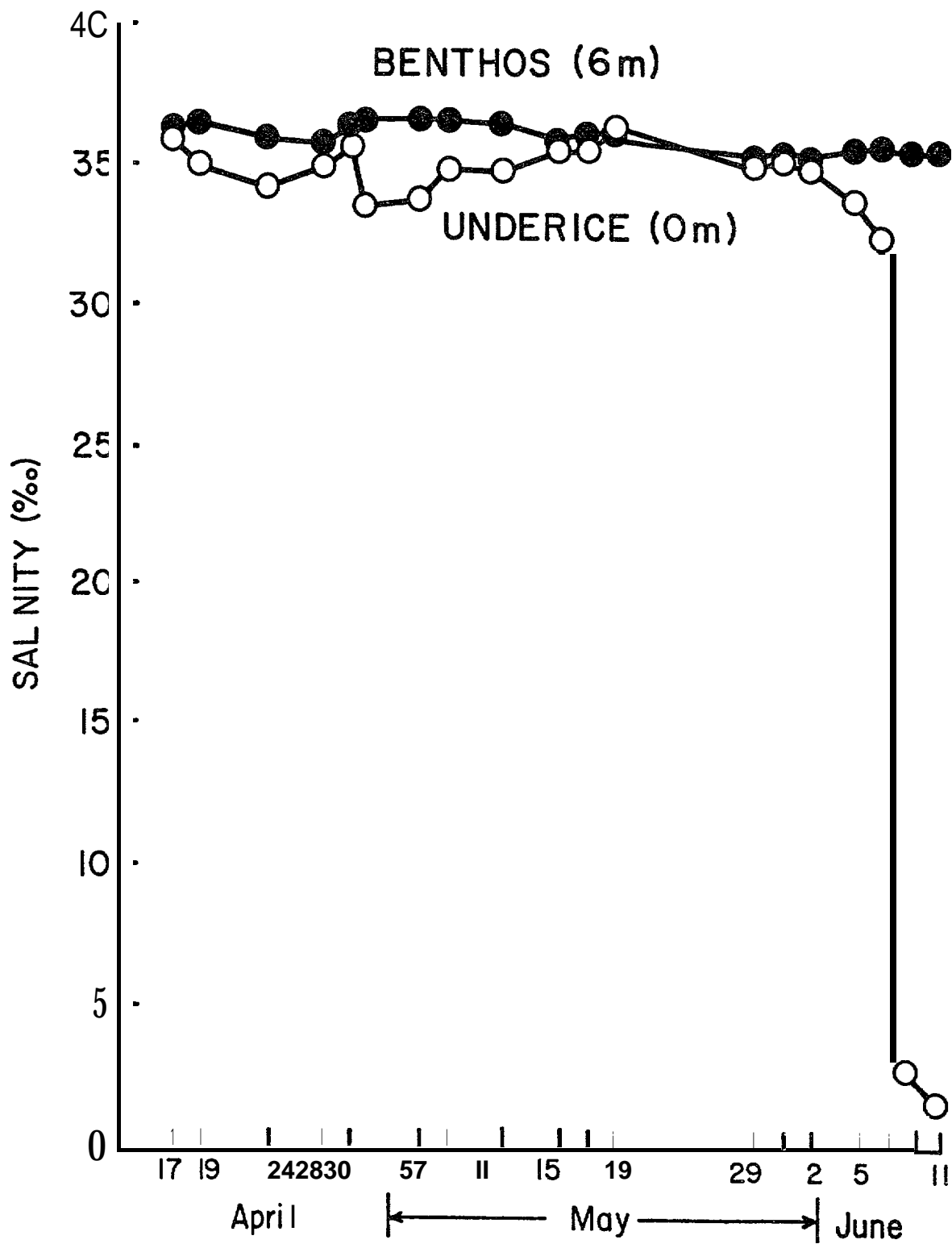


Figure 26. Salinity of water adjacent to the ice undersurface and the sediment surface during the spring, 1980 at the Narwhal Island ice station during Project Sea Ice-80.

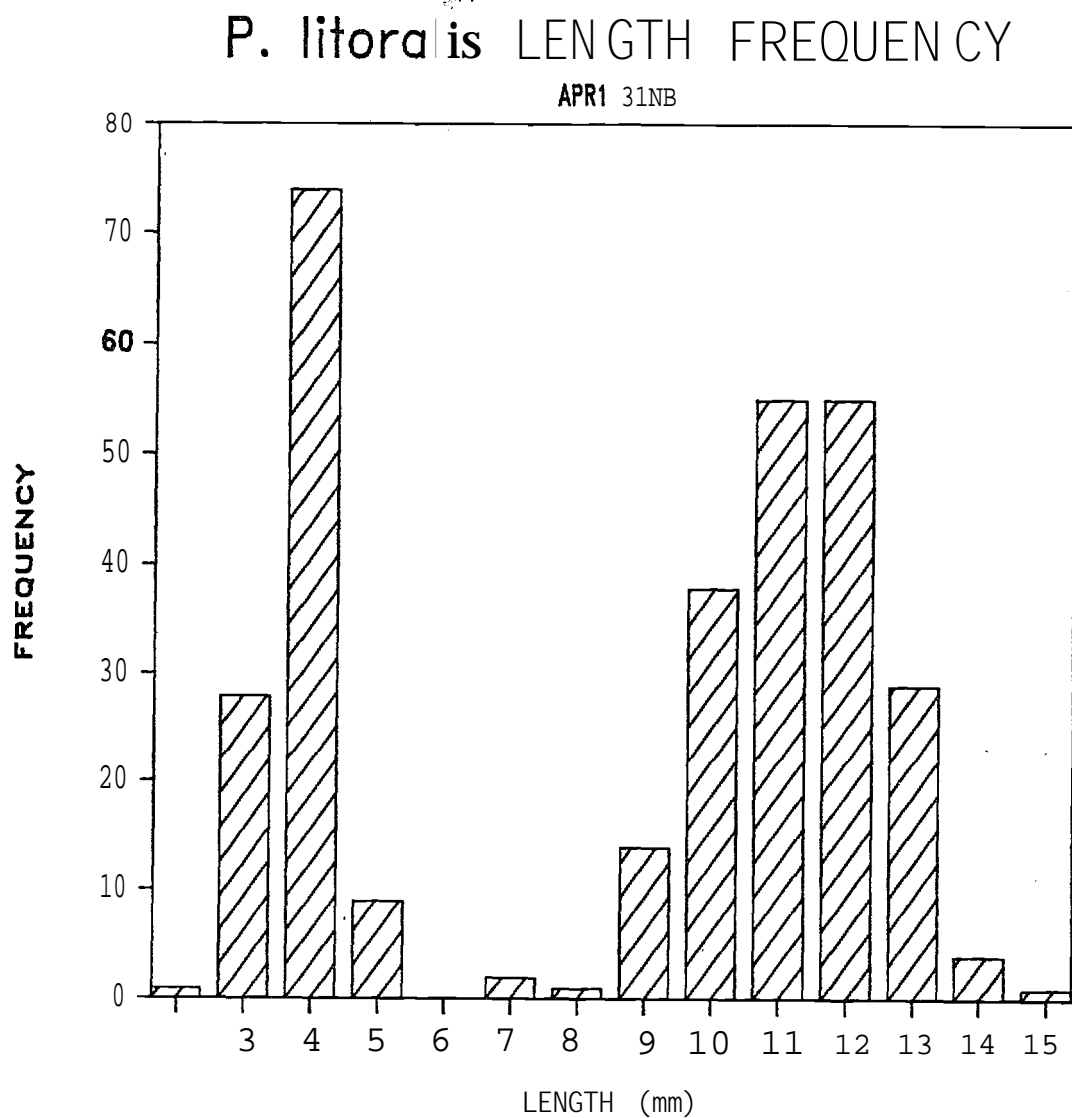


Figure 27. Length-frequency structure of the *Pseudalibrotus litoralis* populations in the ice environment ~~at the Narwhal Island ice station,~~ 13 April 1980.

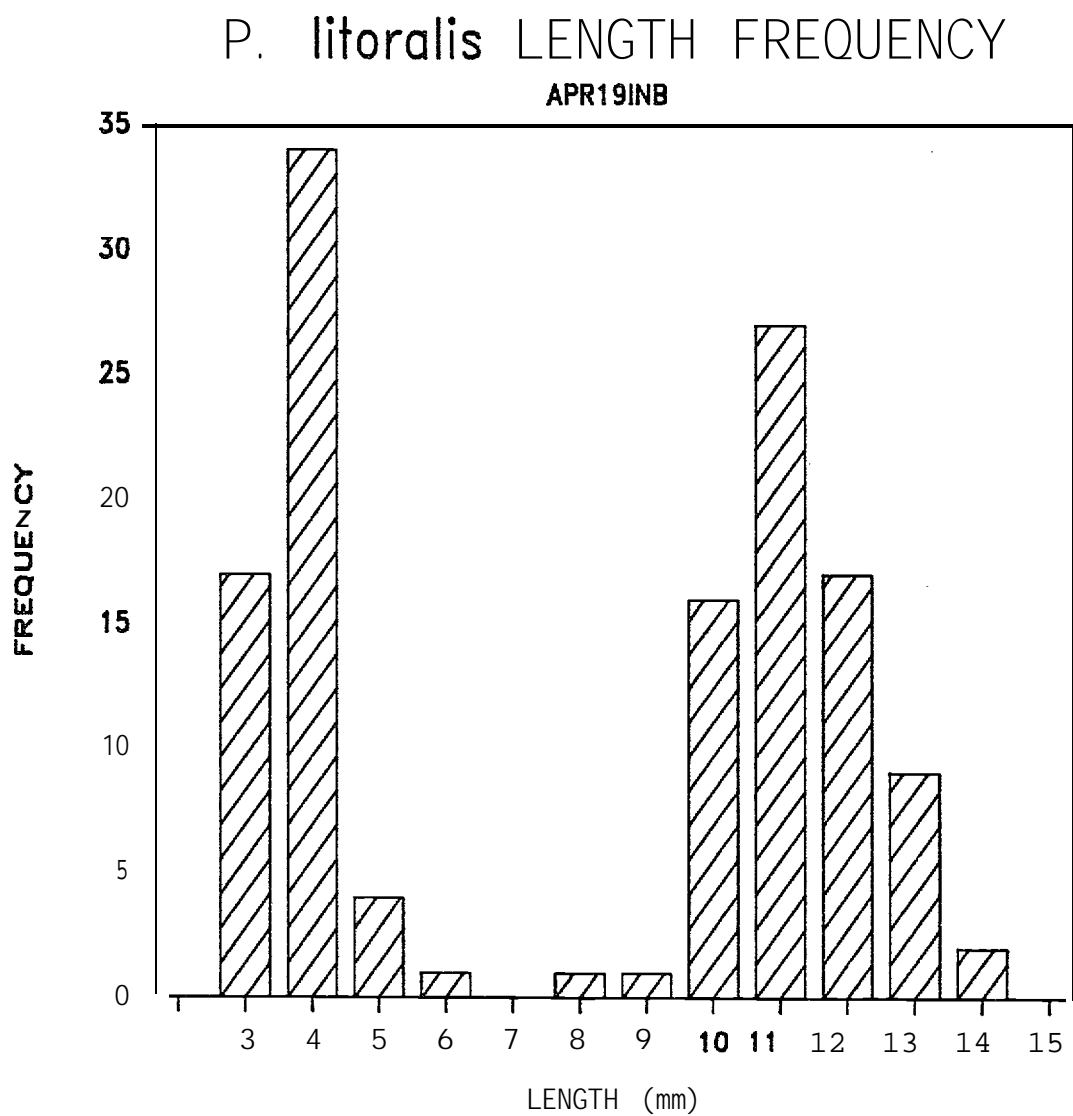


Figure 28. Length-frequency structure of the *Pseudalibrotus litoralis* populations in the ice environment at the Narwhal Island ice Station, 19 April 1980.

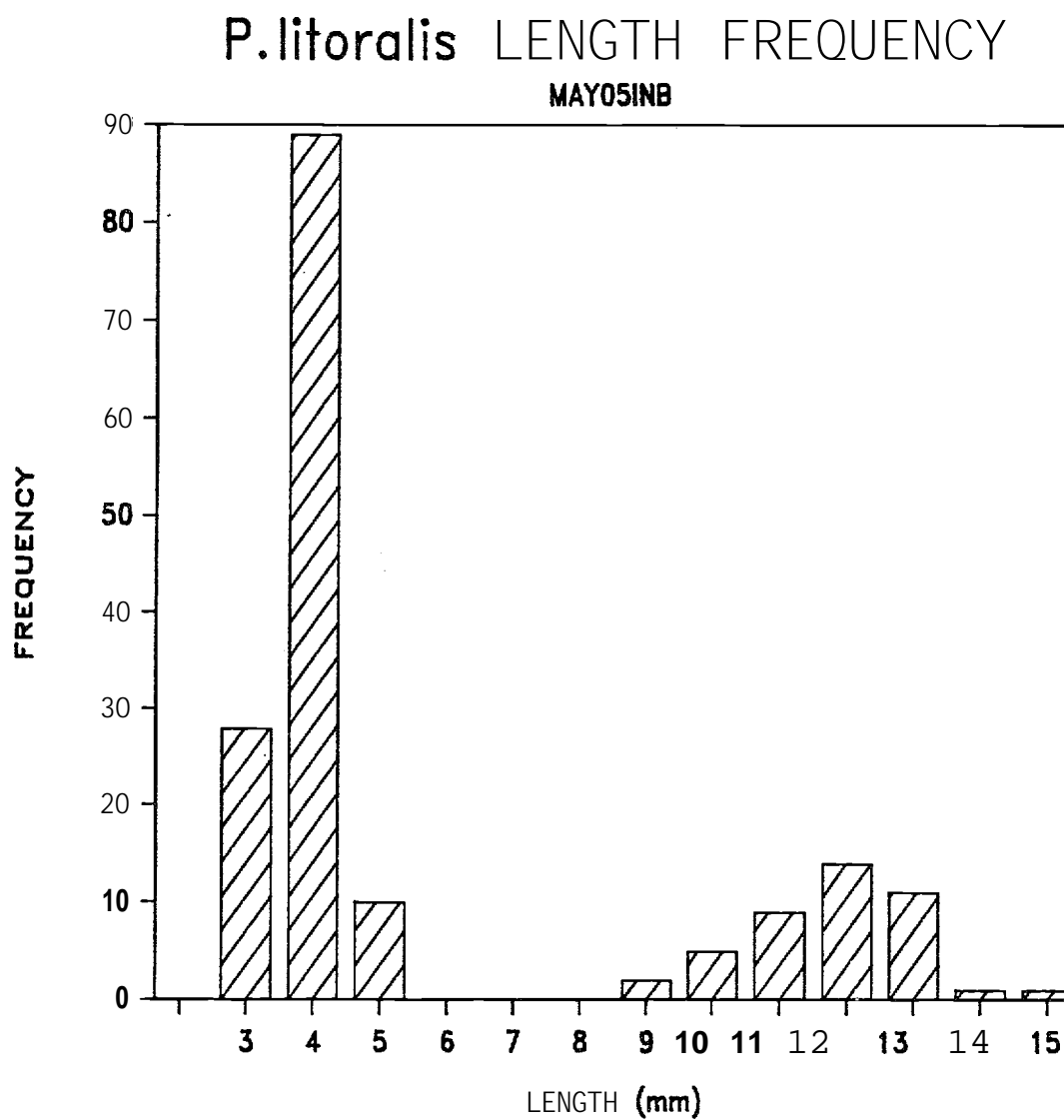


Figure 29. Length-frequency structure of the Pseudalibrotus litoralis populations in the ice environment at the Narwhal Island ice station, 05 May 1980.

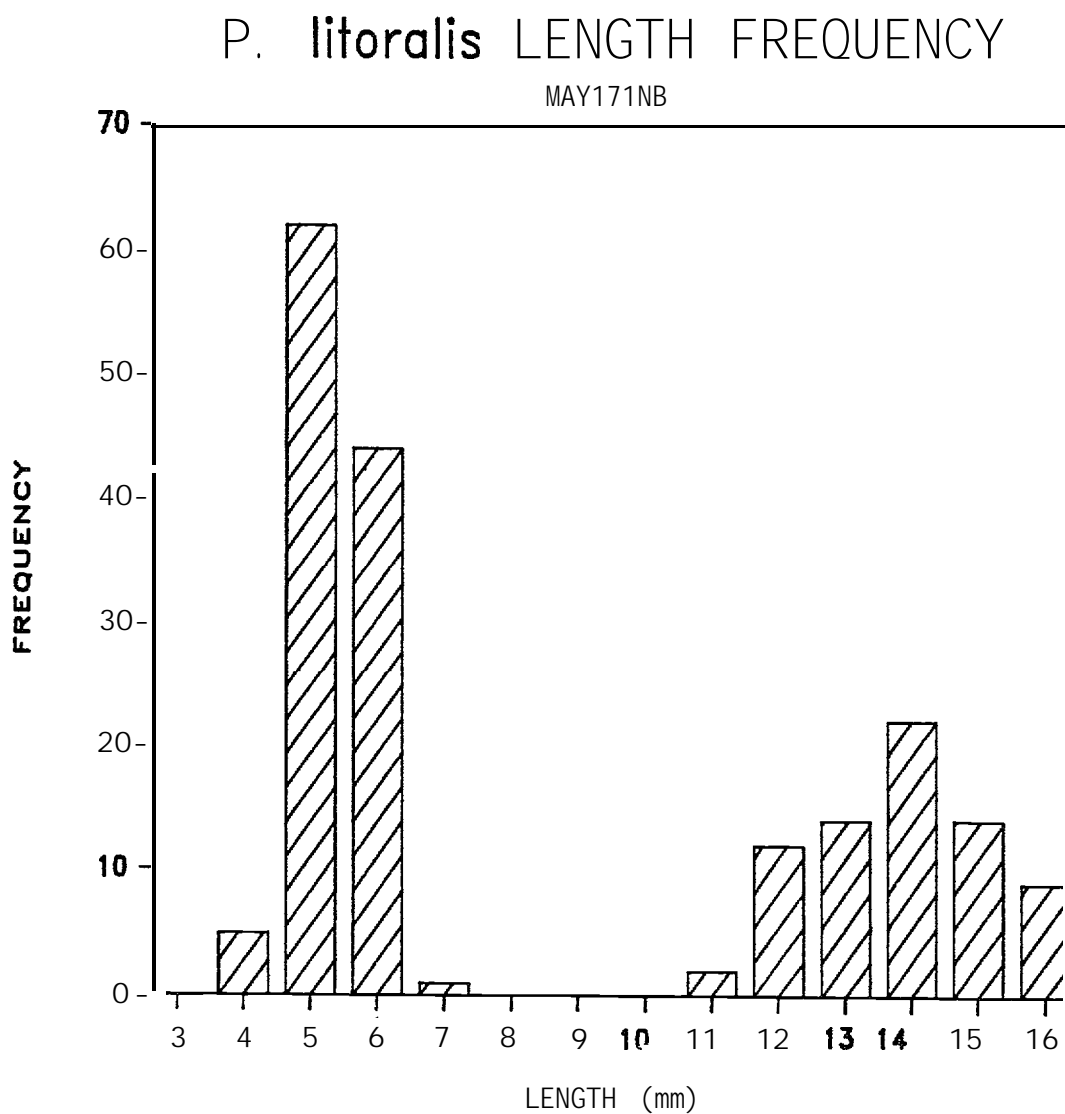


Figure 30. Length-frequency structure of the Pseudalibrotus litoralis populations in the ice environment at the Narwhal Island ice s'tation, 17 May 1980.

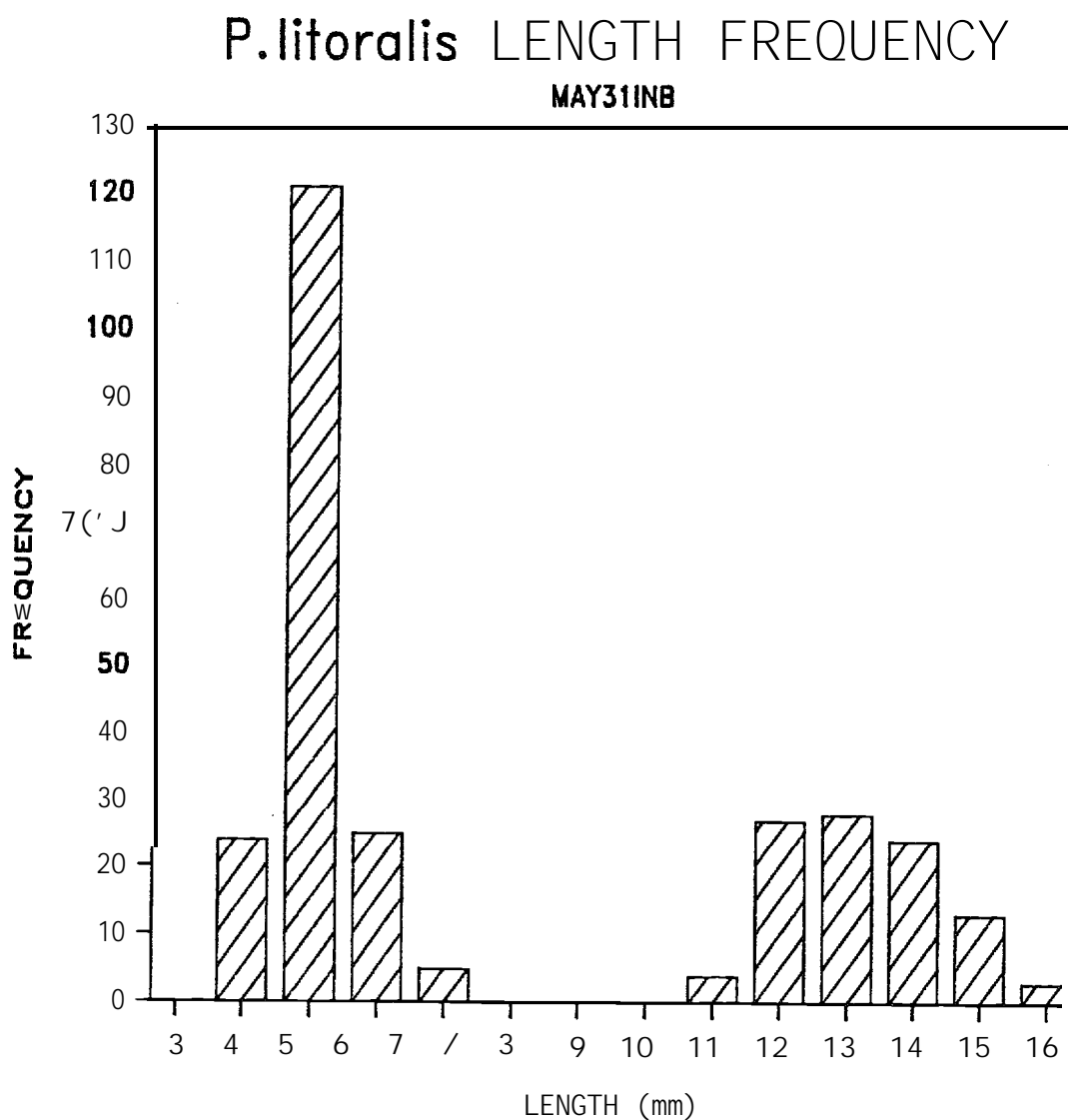


Figure 31. Length-frequency structure of the *Pseudalibrotus litoralis* population in the ice environment at the Narwhal Island ice Station, 31 May 1980.

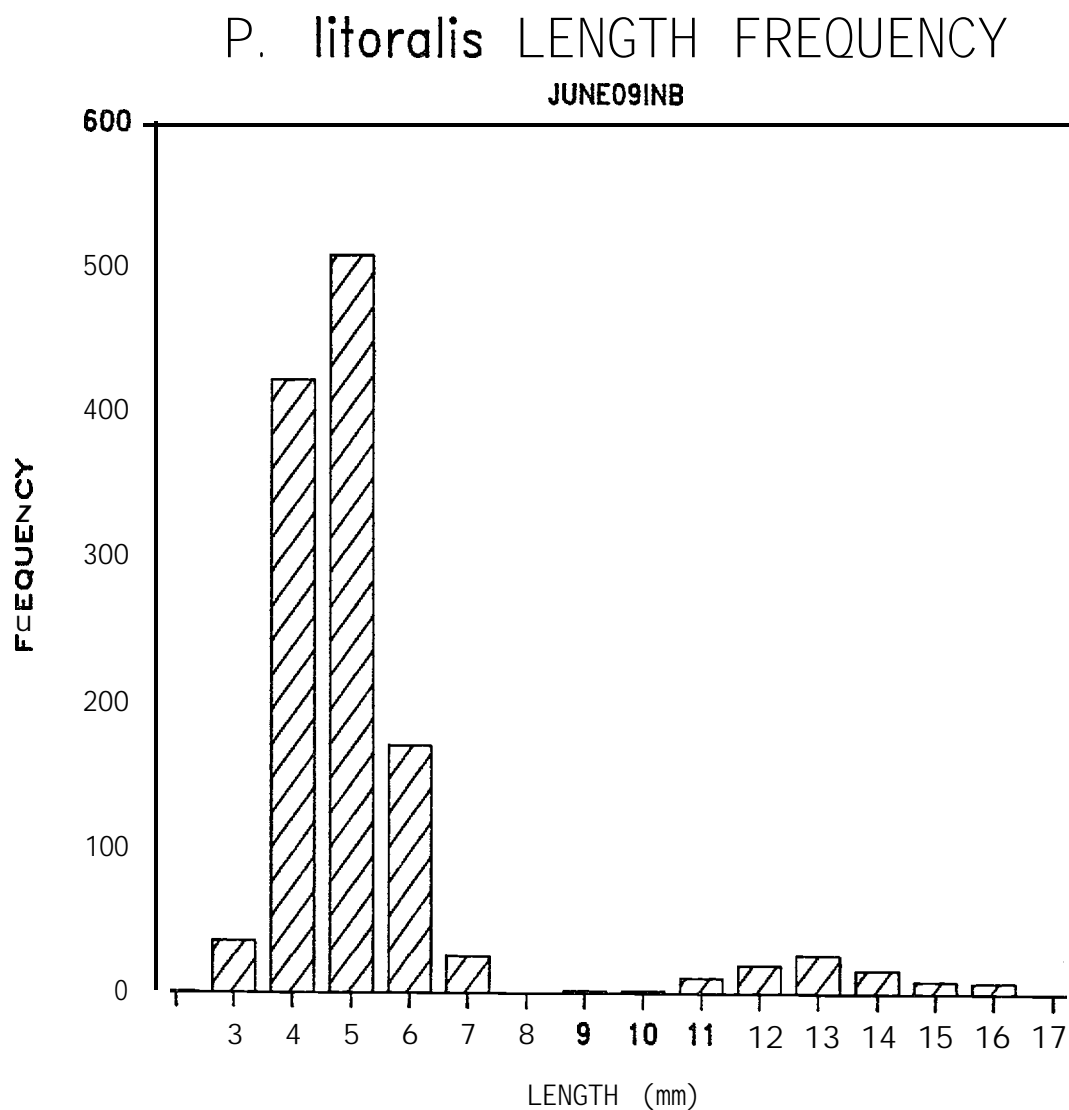


Figure 32. Length-frequency structure of the *Pseudalibrotus litoralis* population in the ice environment at the Narwhal Island ice station, 09 June 1980.



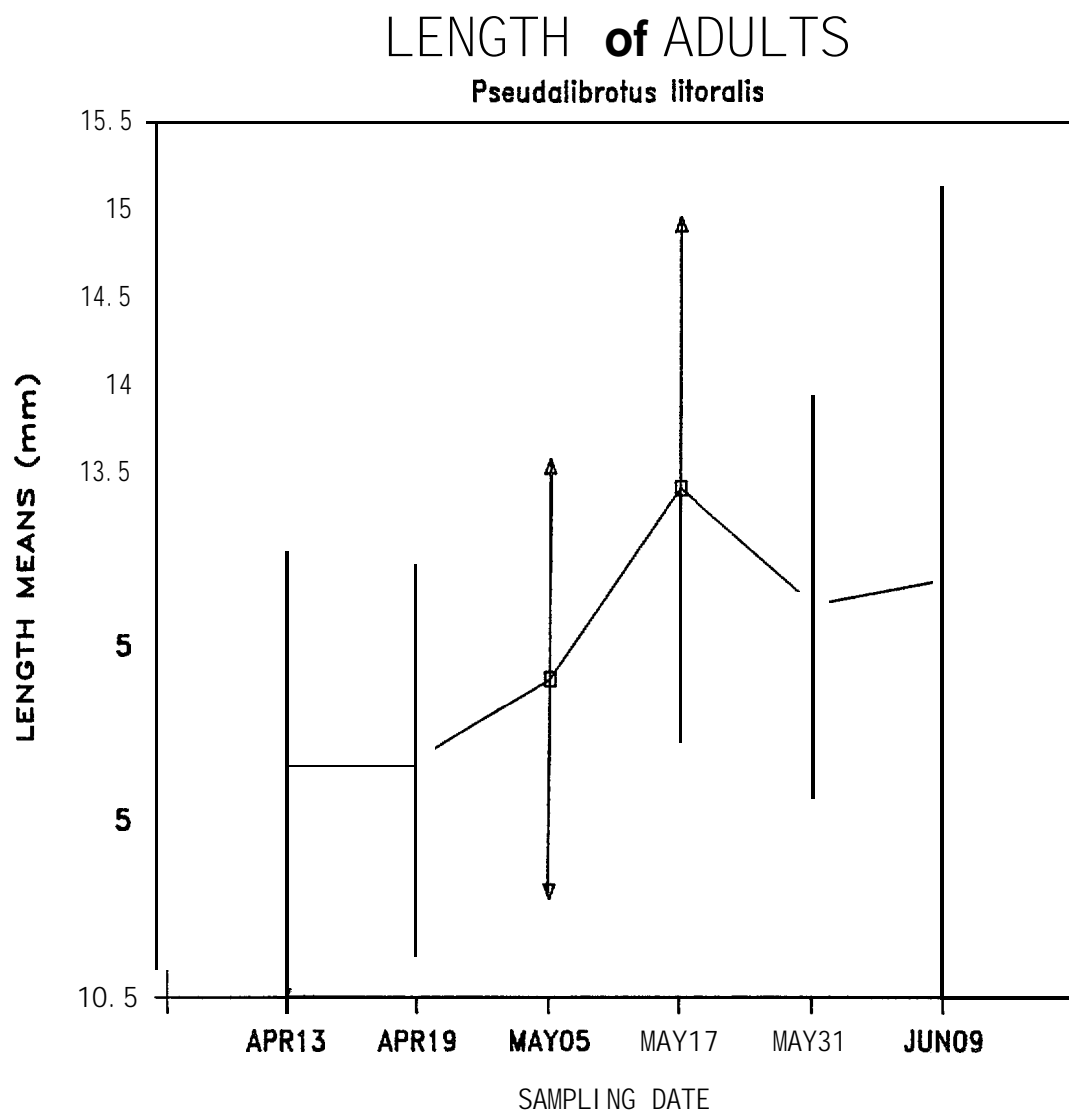


Figure 33. Length of adult *Pseudalibrotus litoralis* populations in the ice environment at the Narwhal Island ice station, 1980. Means  $\pm$  1 standard deviation.

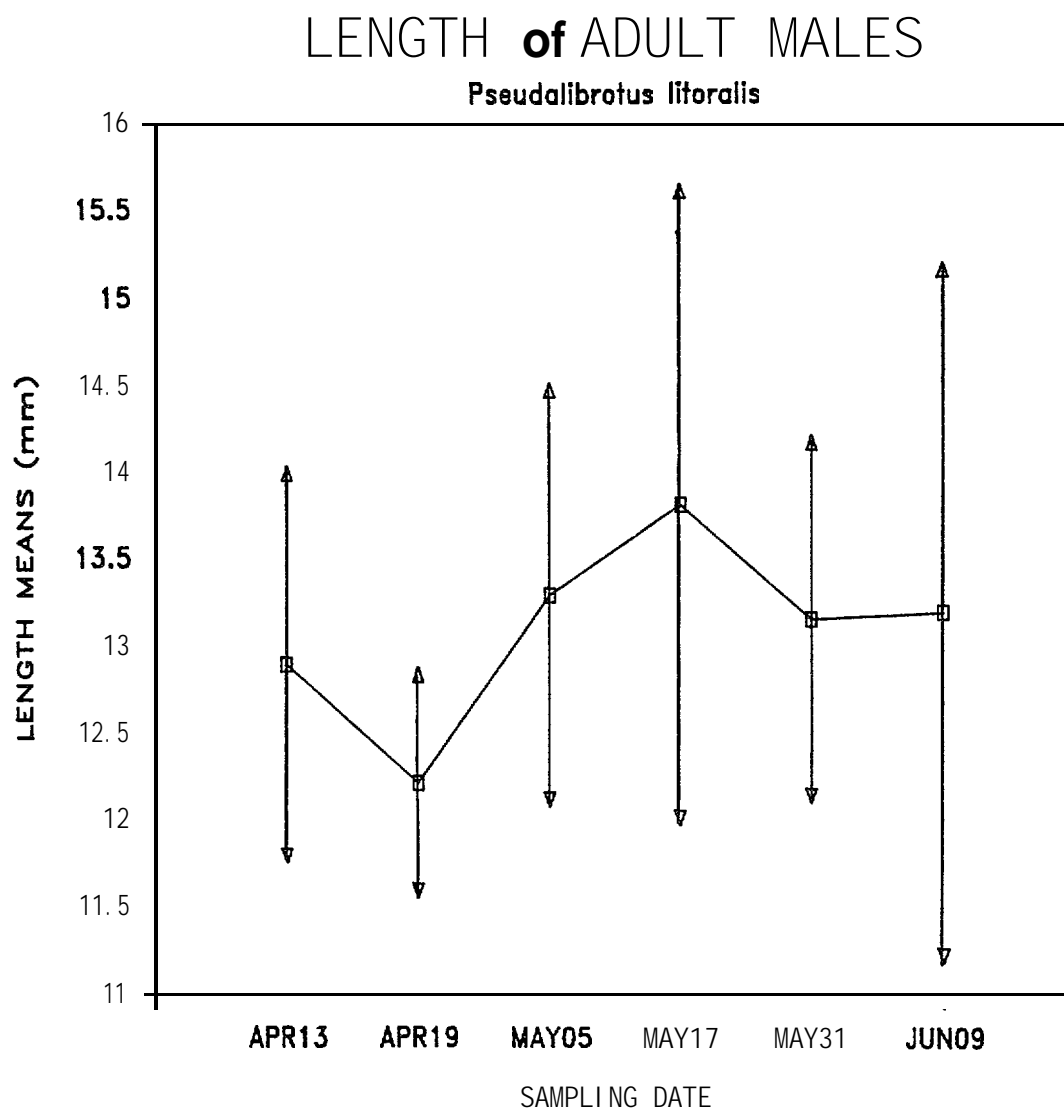


Figure 34. Length of adult male *Pseudalibrotus litoralis* populations in the ice environment at the Narwhal Island ice station, 1980. Means  $\pm$  1 standard deviation.

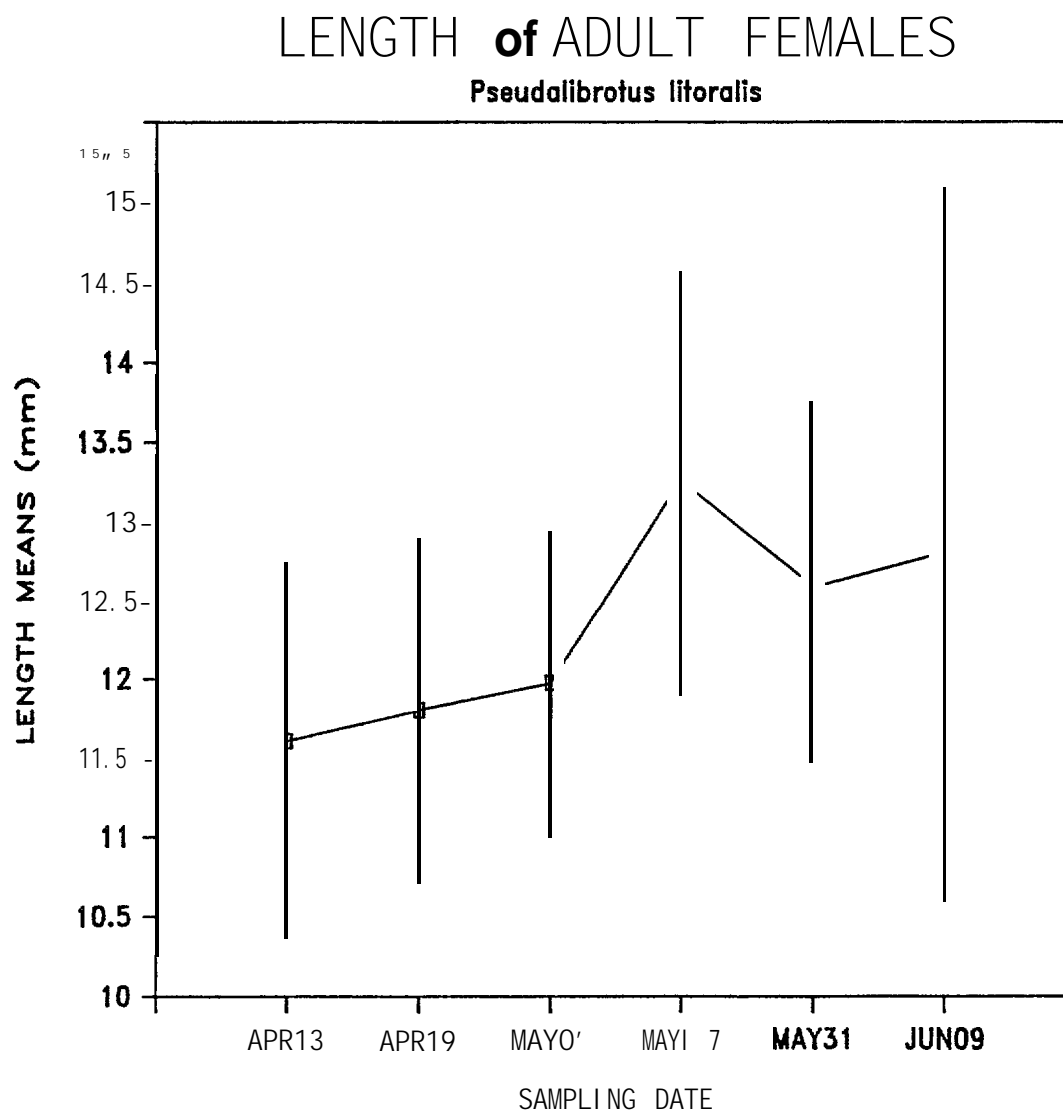


Figure 35. Length of adult female *Pseudalibrotus litoralis* populations in the ice environment at the Narwhal Island Ice Station, 1980. Means  $\pm$  1 standard deviation.

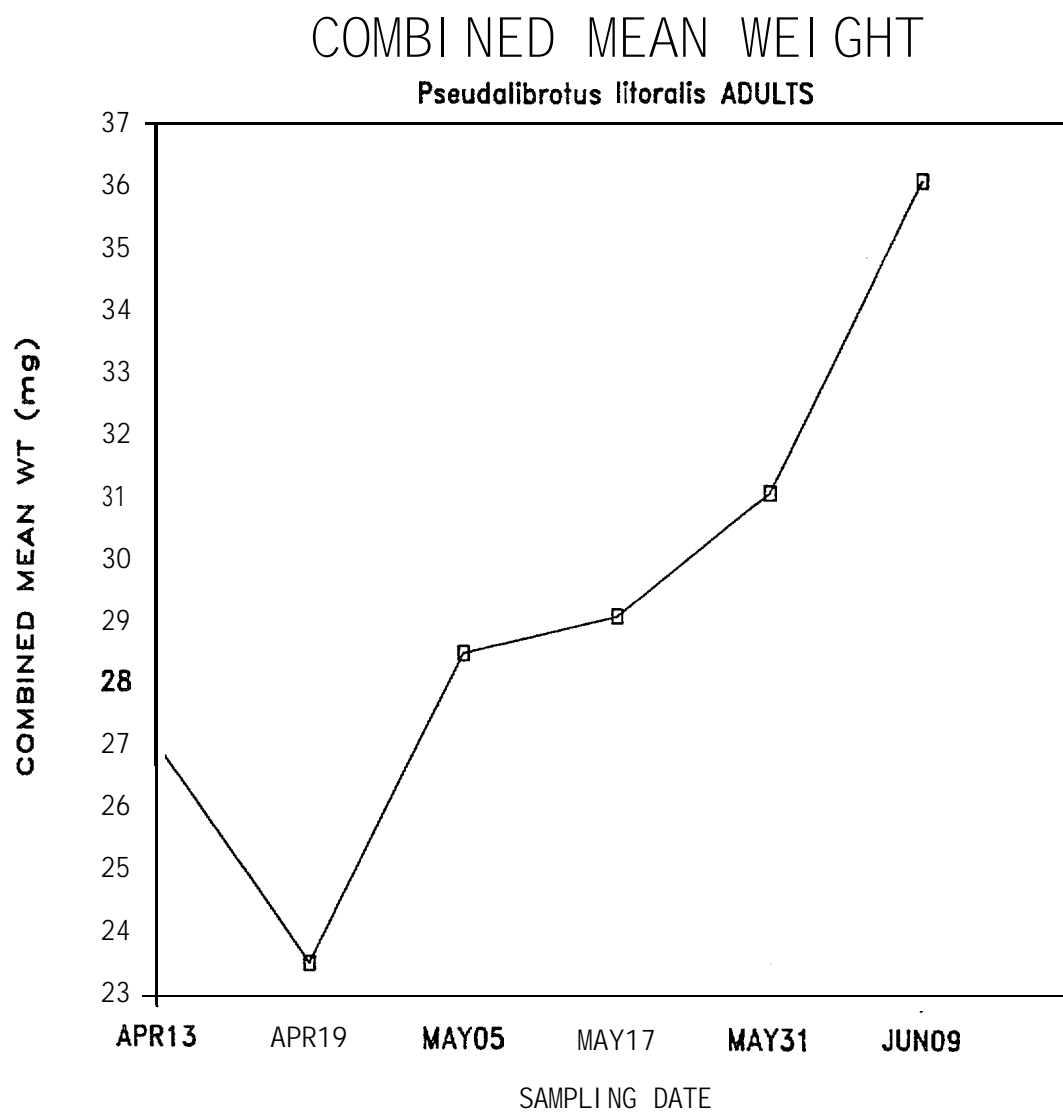


Figure 36. Combined mean weight (wet preserved) of *Pseudalibrotus litoralis* adults in the ice environment at the Narwhal Island ice station, 1980.

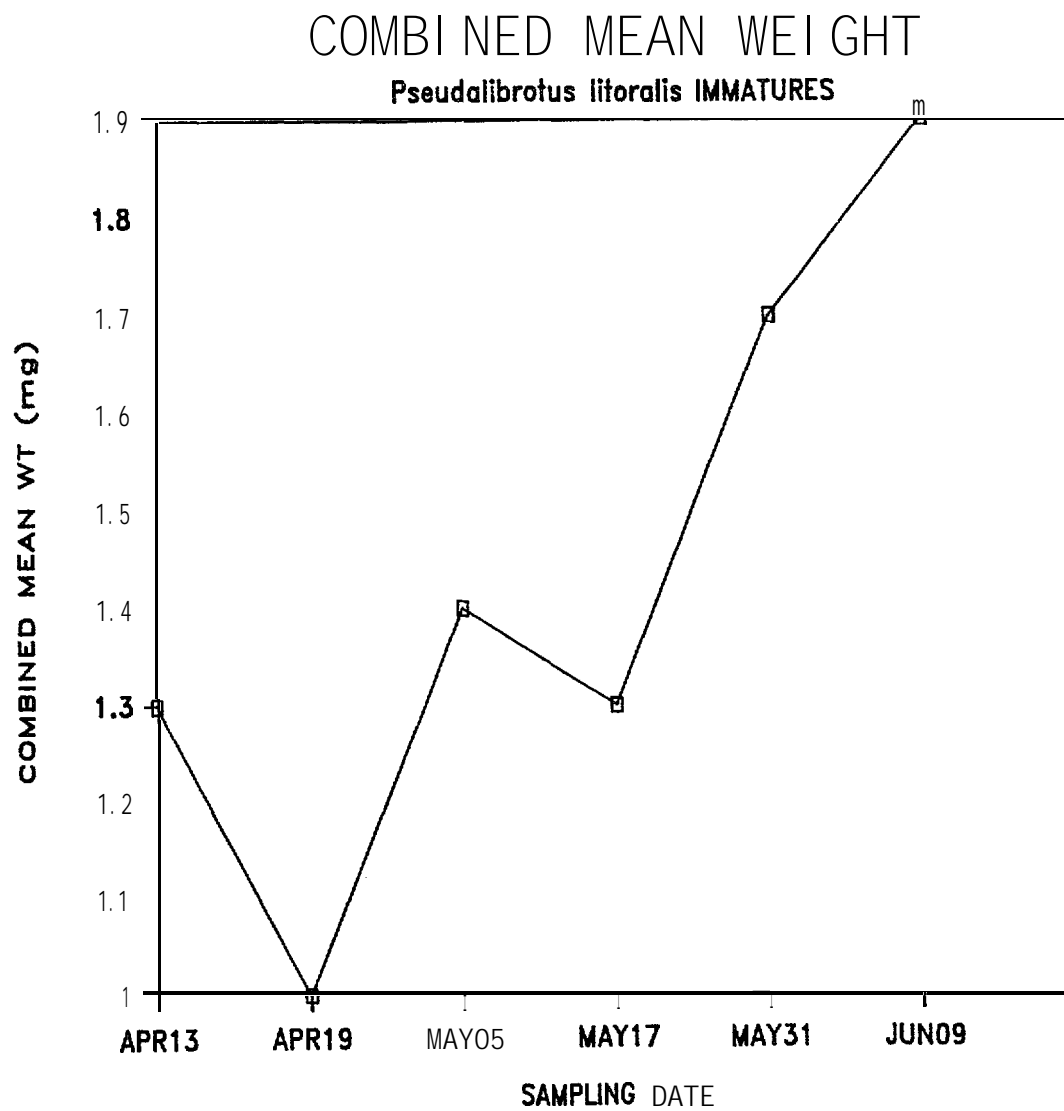


Figure 37. Combined mean weight (wet preserved) for *Pseudalibrotus litoralis* in the ice environment at the Narwhal Island ice Station, 1980.

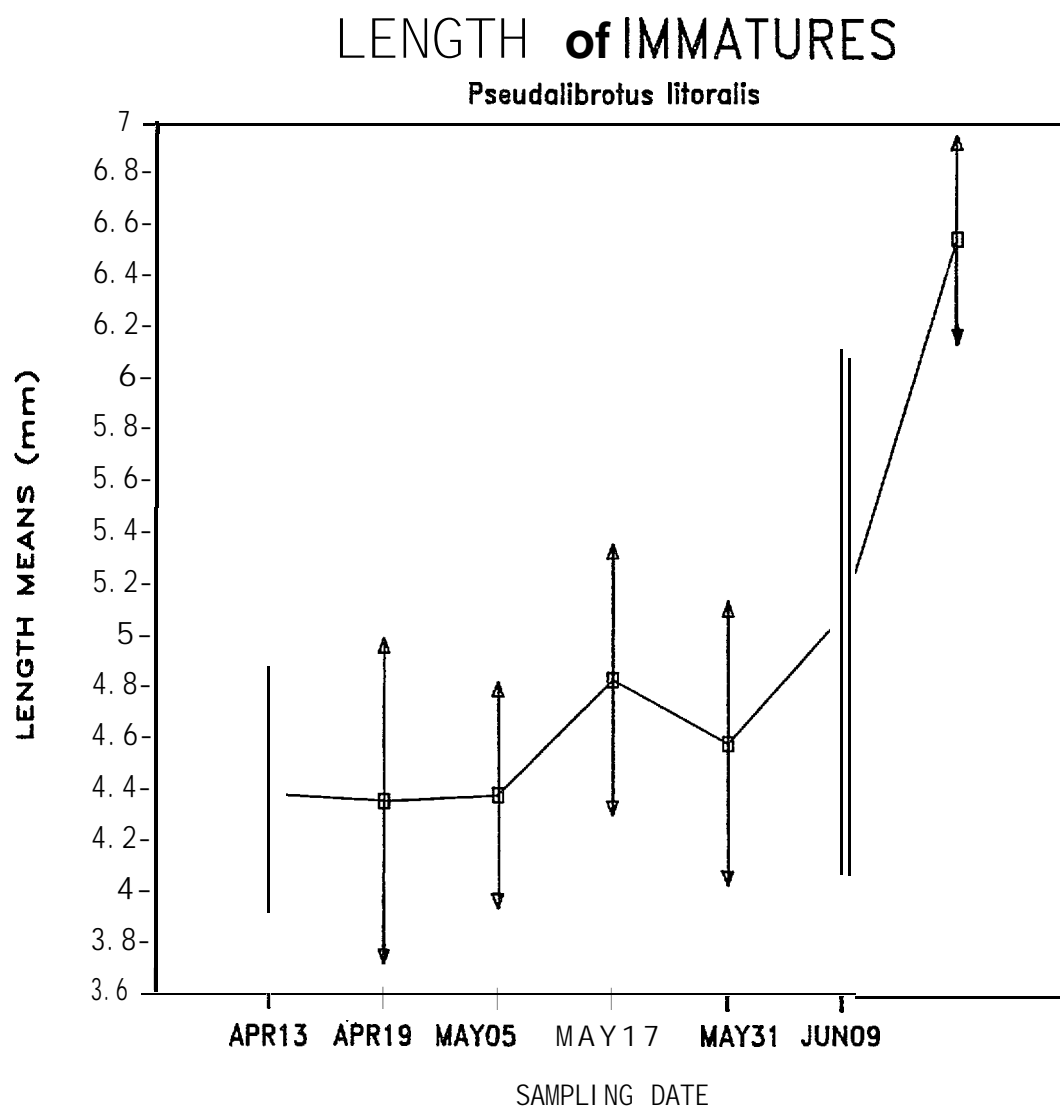


Figure 38. Length of immature *Pseudalibrotus litoralis* populations in the ice environment at the Narwhal Island ice station, 1980. Means  $\pm$  1 standard deviation.

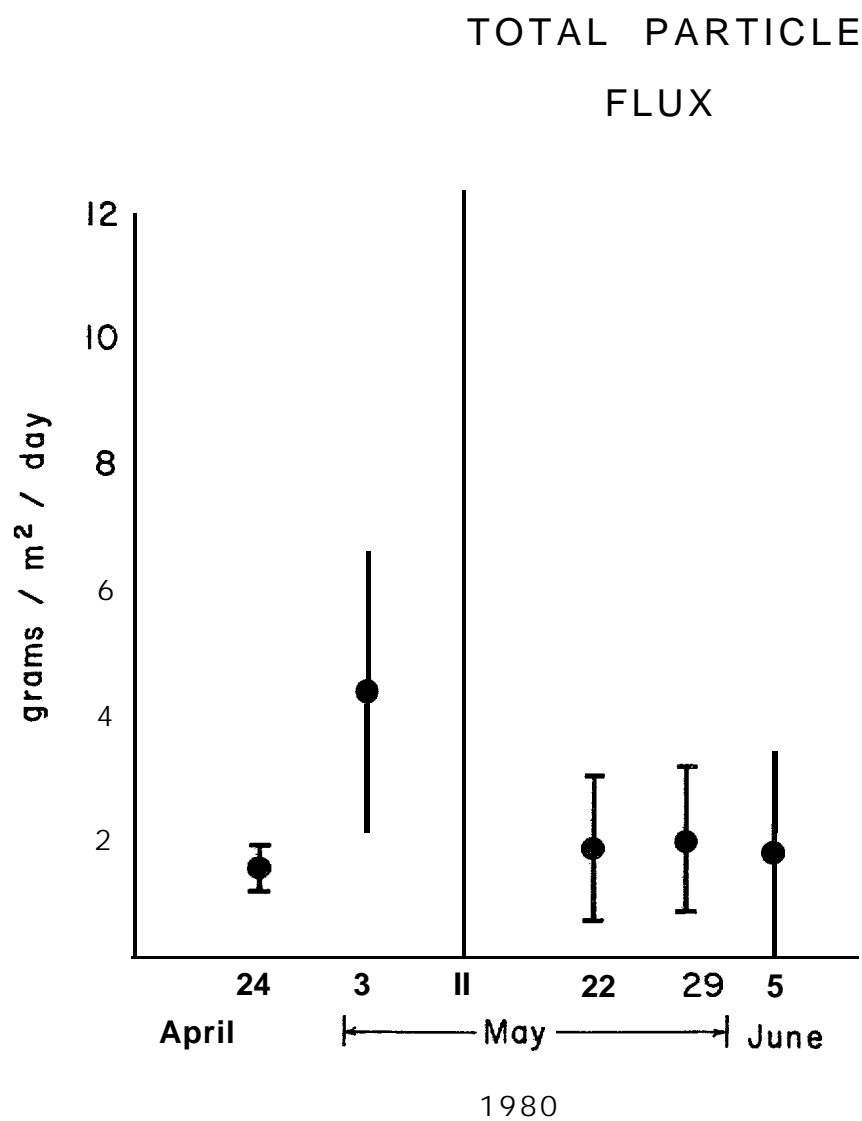


Figure 39. Total mass flux in grams to the sediment surface during spring, 1980, at the Narwhal Island ice station.

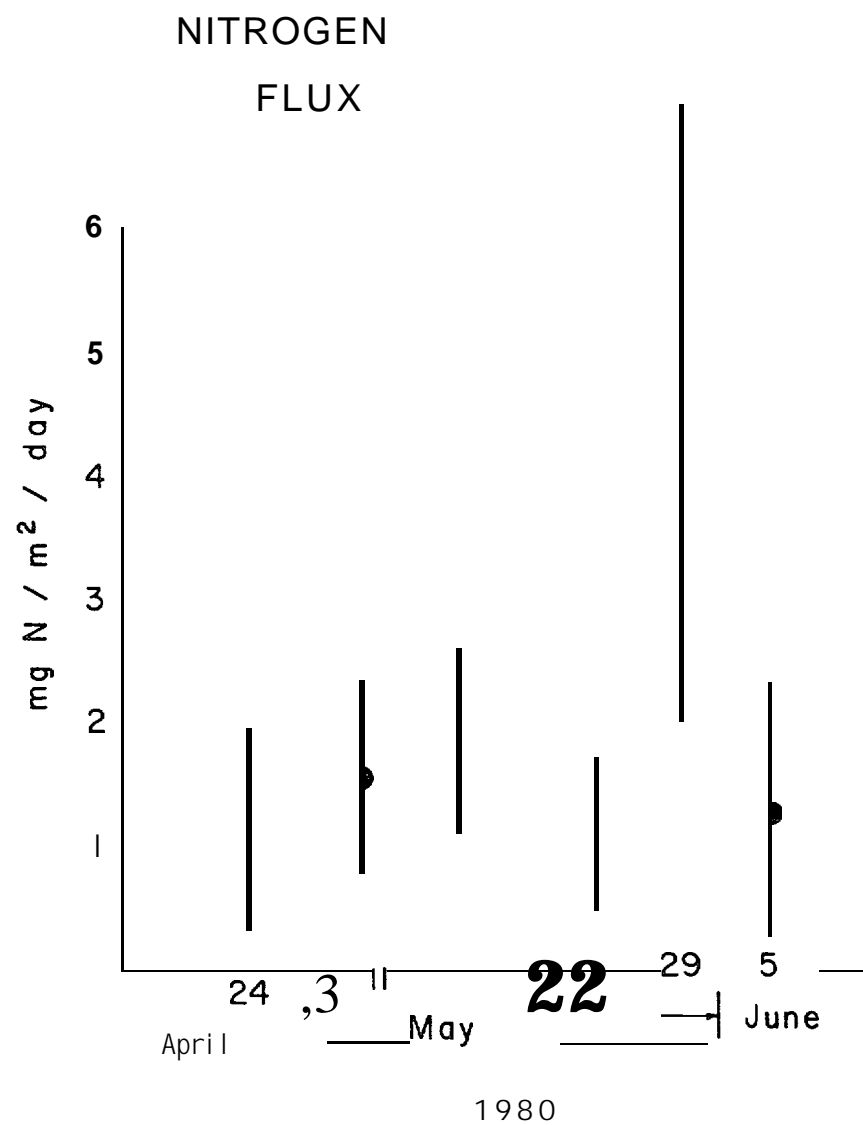


Figure 40. Flux of nitrogen to the sediment surface during spring, 1980, at the Narwhal Island ice station.



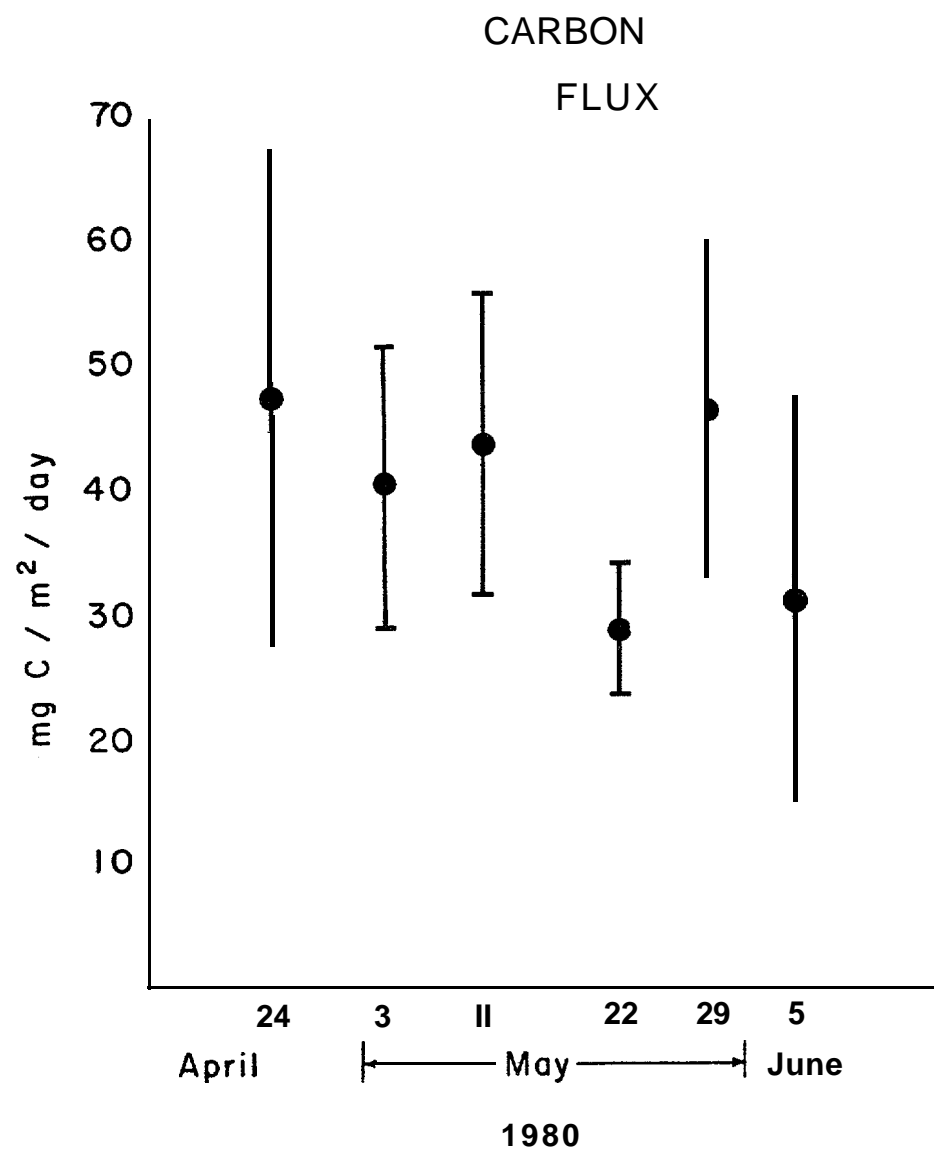


Figure 41. Flux of carbon to the sediment surface during spring, 1980, at the Narwhal Island ice station.

rial appeared as pigmented areas on the glass-fiber filter surface that consisted of generally amorphous matter. Individual diatom tests could be recognized by examination with the scanning electron microscope. Two recognizable fecal pellet types varied over the spring months with contrasting patterns of abundance (Figure 42). The larger pellets formed by the epibenthic mysid Mysis relicts were most abundant at the beginning of the collection series and then steadily declined. On the other hand, the smaller fecal pellets, from the amphipod Pseudalibrotus litoralis, rose in abundance to a peak on May 19, 1980, and then rapidly declined. A series of photomicrographs and scanning electron micrographs illustrate these pellets and their contents (Appendix III: Figures 55-63). The M. relicts pellets contained a complex matrix of generally unidentified material, though some diatom tests and possible crustacean fragments are present. The P. litoralis pellets are comprised almost entirely of numerous ice diatom tests.

#### D. Voucher collections

Species of polychaete worms and pelecypod molluscs encountered during the OCSCEAP studies of RU #006 in the southwest Beaufort Sea have been submitted to the Marine Invertebrate Zoology section, California Academy of Sciences (Appendix IV: Tables 38 and 39).

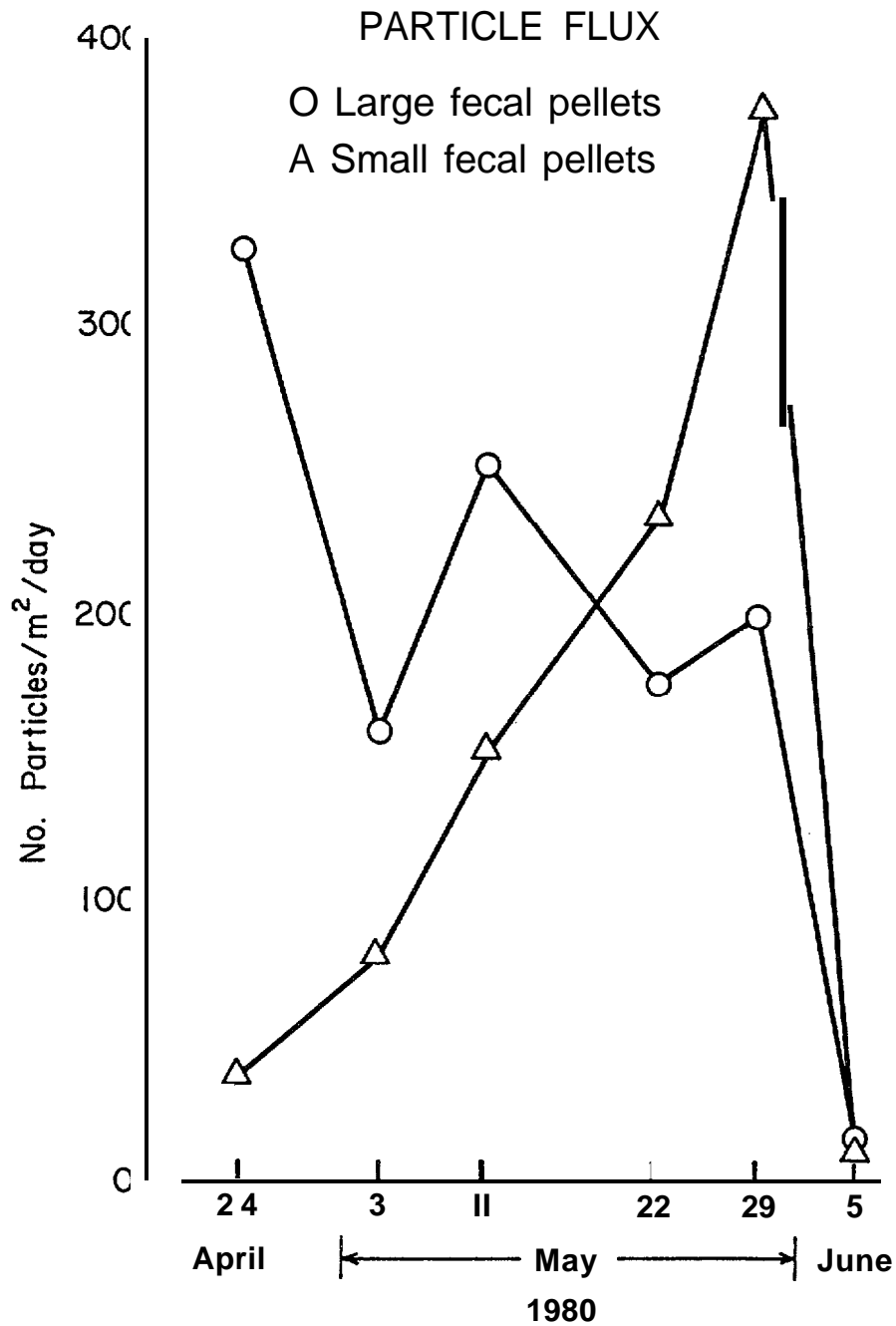


Figure 42. Flux of fecal pellets to the sediments during the spring, 1980 at the Narwhal Island ice station. The large pellets are formed by the epibenthic mysid Mysis relicta and the small pellets by Pseudalibrotus litoralis.

## VII. Discussion

### A. Benthic continental shelf fauna: cross-shelf trends

Low faunal abundance, species richness, and biomass at the 5 m station indicate an inhospitable environment for biological or physical reasons. In the arctic coastal zone the sea ice appears to be the most important controlling factor. The deeper drafts of pressure ridge keels rest on the sediments at the shallowest depths. Highly saline water forms beneath the ice as salt is excluded and drains downward through the ice during the winter months (Gade et al., 1974). This bottom water layer can become very cold, adding to the stress encountered by the benthic organisms in this zone. There also can be direct mechanical effects of the sea ice on the sediment cover in areas where ice-push builds ridges, levees or jumbled terrestrial fields of ice blocks (Wadhams, 1980). In some areas ice-push can drastically alter the character of the shallow sea floor and presumably damage the benthic fauna. Benthos from several 5 m stations along the coast (Carey et al., unpublished ms) exhibit depressed levels of abundance in areas of known ice over-ride of adjacent low-lying gravel barrier islands.

Lowered summer salinities at these shallow depths, caused both by ice melt and the summer river runoff probably also create a harsher environment by increasing the total salinity range over which the animals must survive (Appendix I: Table 15).

It is also possible that high predation pressure from several of the benthic-feeding migratory waterfowl deplete these shallow water standing stocks. Eider and old squaw ducks are extremely plentiful during their summer feeding and breeding season and feed on shallow benthos, particularly bivalve molluscs (Divoky, 1978).

The inner continental shelf of the Beaufort Sea (5-25 m depth) is subject to strong environmental disturbances in salinity, turbulence turbidity and ice gouging. These are strongly seasonal, and several are zoned by depth in spite of the narrow range studied. Most of the bivalve distributions, faunal abundances and functional group compositions (feeding type, reproductive pattern, and substrate orientation) tend to be homogeneous along the length of the Alaskan Beaufort coast (Carey et al., 1984). At the deepest stations, however, there seems to be a selection for the deposit feeding mode of existence in the siltier sediments. These results suggest that the fluctuating environment has selected for a generalized assemblage of animals.

Polychaetous annelids, collected in coastal waters (5-25 m) along the length of the Alaskan Beaufort Sea coastline, represent a relatively uniform and speciose fauna (105 species) (Carey et al., unpublished ins). Species richness and total numbers vary little with depth and longitude. Generally there are few dominant species; a large species group (39) is widely distributed throughout the environment studied. At the shallowest depths, however, selective surface deposit feeders predominate in the sandy sediments found there. Predators and non-selective deposit feeders are relatively uniform and low in abundance through the region. In spite of a physically structured environment, compositional similarity of the fauna is greater than expected by chance from Point Barrow to Barter Island (Appendix I: Table 16). Several processes disturb the environment, probably selecting for an environmentally tolerant fauna.

On the average, the total benthic macrofaunal community varies in numerical density and biomass over a year's period (Carey, unpublished ins). These changes are more marked on the outer half of the shelf than on the inner shelf at 25 m depth. Small organisms increase in total numbers during the late summer indicating an increase of the population size of small species and perhaps the recruitment of juveniles of the macrofauna to the benthic community. An analysis of population size structure of three species of bivalve molluscs and four species of polychaete worms does not, however, demonstrate a seasonal and discrete burst of recruitment to these populations. It appears that most benthic invertebrate spe-

ties reproduce throughout much of the year by producing small numbers of **yolky lecithotrophic** eggs.

The mega-epifauna species distributions, derived from both the photographs and trawl collections, demonstrate a general trend toward very broad depth distributions (Figure 11). These data also illustrate that the shallowest, more variable stations support few species of **mega-epifauna**.

Comparisons of the abundances of the **benthic** megafauna and **macrofauna** demonstrate a general negative correlation between the two groups (Figure 43). Where the megafauna are most abundant, the **macrofauna** tend to be depressed in numerical density. This relationship could be caused by direct predation on the larvae, juveniles or adults of the macrofauna, or an environment feature such as **detrital** food supply could have a differential effect on the two faunas.

#### B. Ice fauna (Narwhal Island)

During the last ten years the primary production of the ice algae has been reported to contribute up to 40% of the total carbon fixed by marine plants in the arctic ecosystem (Alexander, 1974; Homer, 1977; Homer and Schrader, 1982). Because this late spring ice algal production on the undersurface of sea ice occurs before plant production can be supported in the water column or on the sediments, this early source of carbon significantly extends the arctic growing season (Alexander and Chapman, 1981). The undersurface of the ice supports an abundant invertebrate fauna, and the algal community is an important source of energy for these organisms migrating to this interface (Cross, 1982; Carey and Montagna, 1982; Kern and Carey, 1983). These animals in turn form the basis of an abbreviated food web that links the underice fauna to fishes and to seabirds and seals (Bradstreet, 1982; Bradstreet and Cross, 1982).

SCUBA observations and sectioned ice core samples indicate that the **sympagic** amphipod species occupy a variety of sub-habitats. Generally the **macrofauna** occupy the lower 5 to 10 cm of ice (Pett et al., 1983), though individuals were observed living in brine channels (Lewis and Milne, 1977; Cross, 1982; Newbury, 1983) and partially or fully embedded within the ice (Gulliksen, in press). Green and Steele (1975) report that Gammaracanthus loricatus is the only **amphipod** species associated with ice stalactites and may at times be frozen within them. On occasion Apherusa glacialis occupy the brine channels, though they are mostly on the ice undersurface (Cross, 1982). A. glacialis tends to be patchy in distributions with aggregations of juveniles **concentrated** on clumps and strands of ice algae.

In contrast to the species composition of the ice macrofauna in deeper and offshore waters, whether in fast ice or pack ice, the gammarid amphipod Pseudalibrotus litoralis dominates the ice **macrofaunal** community on the inner shelf in water depths of about 10 m (Green and Steele, 1975; Carey, 1982).

The large numbers of animals found within the ice of the Beaufort Sea is surprising. Andriashev (1968) provided the only data in the literature that can be used for quantitative comparisons, and his data were from the Antarctic. He found solitary **polychaete** individuals, **cyclopoids** up to several hundreds/m<sup>2</sup>, **harpacticoids** (including species of Harpacticus and Dactylopodia) up to hundreds/m<sup>2</sup>, and amphipods up to 3040/m<sup>2</sup>. No information was given for **turbellarians**, or for nematodes which was the dominant group in the arctic samples. Comparing the data sets on a per unit area basis (Table 1), it is apparent that the overall abundance of the ice fauna is much greater in the samples collected from the Arctic. Amphipods were the only group which had a greater density in the Antarctic. It is possible that the Beaufort Sea site was an unusually productive one, but there is no evidence to support this idea. The study area was visually indistinguishable from surrounding ice pans when viewed from a helicopter. Chlorophyll *a* values measured in the ice close to the Narwhal Island study grid (Homer and Schrader, 1981) are similar to those recorded elsewhere (Apollonio, 1965), although further sampling in other areas should be performed.

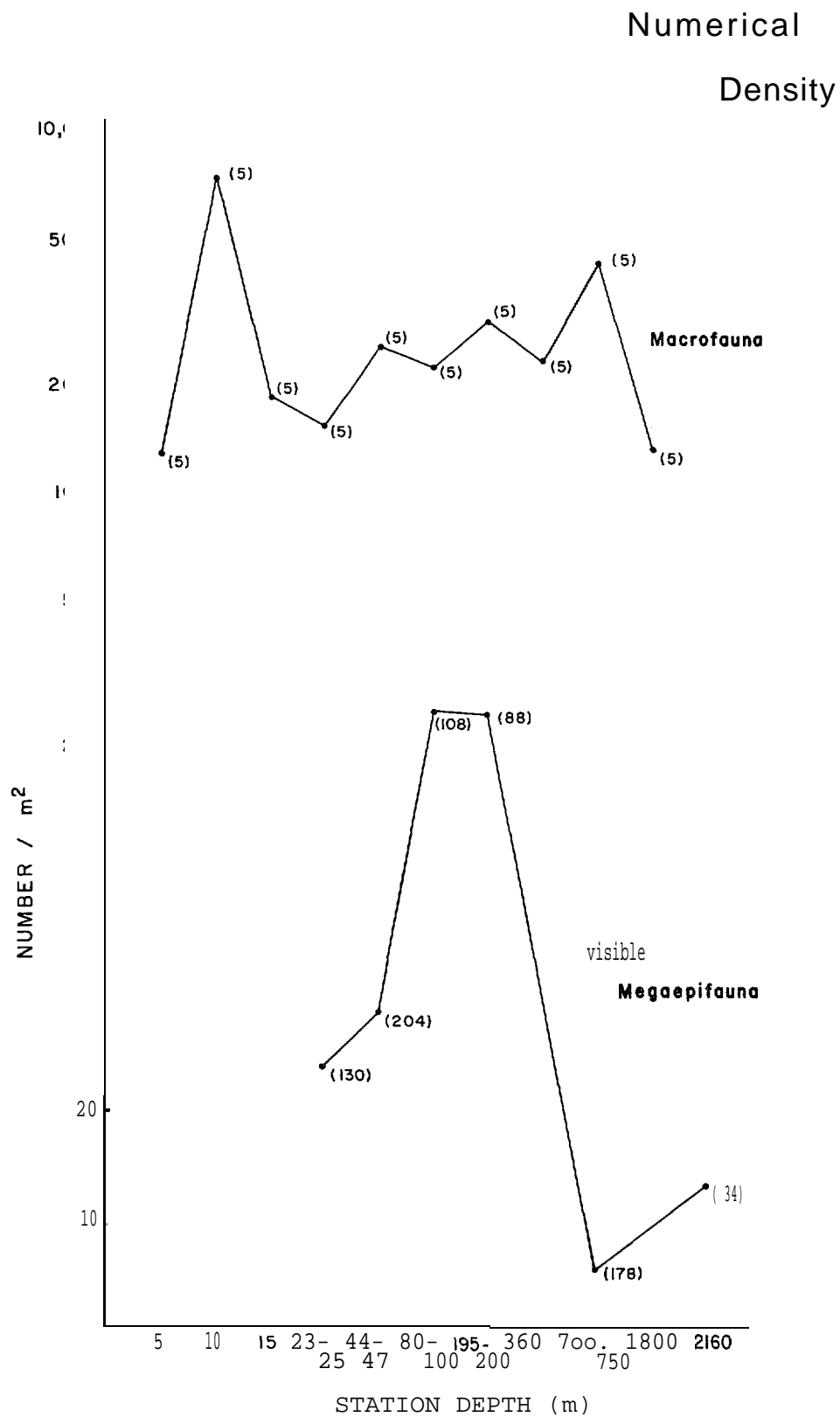


Figure 43. Comparison of the numerical density (means) of the **macrofauna** (>1.0 mm) and mega-epifauna (>13 mm) on the continental shelf - upper slope on the Pingok Island cross-shelf transect. The numbers of grab samples and photographic aerial coverage (m<sup>2</sup>) are indicated in parentheses.

**Table 1.** Abundance of major taxa collected from sea ice in the Antarctic (Andriashev, 1968) and the Beaufort Sea. Values given are number per m<sup>2</sup>. No values for Nematoda or Turbellaria were available from the Antarctic. The minimum densities for taxa collected from the Beaufort Sea were calculated using the lowest mean number per core; the maximum using the highest mean number per core.

Group	Antarctic	Beaufort Sea	
		Minimum	Maximum
Polychaeta	Solitary Individuals	135	5,107
Cyclopoida	Up to <del>Several</del> Hundreds	1,058	7,737
Harpacticoida	Scores to Hundreds	<b>1,079</b>	4,638
Amphipoda	up to 3040	218	1,193
Nematoda	-----	359	25,022
Turbellaria	-----	206	15,167

While the density of the ice fauna was greater than expected (Table 2), it was only around five percent of typical benthic meiofaunal density (Coull and Bell, 1979). This may be due to the ephemeral nature of the fast ice habitat. Seasonal ice is only present in the Beaufort Sea from September or October until around June (Barnes and Reimnitz, 1974), and populations must recolonize the lower layer of this ice each year. There is evidence, using artificial substrates suspended over the bottom, that some meiofaunal groups can rapidly develop large populations in abiotic sediments (Scheibel, 1974). Nematodes and copepods, the most abundant taxa in Beaufort Sea ice, were also the dominant groups colonizing the suspended substrates. This is not surprising since these two groups are typically the most abundant in normal sediments (McIntyre, 1969). At least some of the increase in density in Scheibel's study was due to continued immigration of animals after the sediments had initially been colonized. It is also possible that animals migrated to the ice from underlying sediments during the sampling period. However, nematodes are not able to swim large distances (Scheibel, 1974), and continued movement of these organisms to the ice would depend on passive transport from the bottom by advection. Reproduction was responsible for at least part of the increase in abundance observed in the ice. Gravid females were noted in the ice copepod species Cyclopina gracilis, Halectinosoma sp. and Dactylopodia signata. A few nematodes were examined, and gravid individuals were observed (E. W. Hogue, personal communication). Laboratory studies have shown that the time required for marine nematodes to complete one life cycle varies greatly, and can be as short as less than two weeks (Gerlach and Schrage, 1971). It may be possible that the rapid increase in abundance found for nematodes could largely be due to reproduction rather than passive transport, if the ice species have short life cycles.

Grazing by ice fauna may be important in regulating standing stocks of ice algae. It had previously been suggested that ice algae were free from grazing and that the entire season's reproduction was released into the water column at breakup (Meguro et al., 1967). Nematodes collected from fast ice in the Beaufort Sea had guts filled with diatoms. Most benthic harpacticoids have been found to feed extensively on diatoms (McIntyre, 1969). The large densities of these organisms in the ice suggests that at least some of the algal production may be utilized in situ. Further work is required to determine the extent of grazing by ice fauna.

Environmental conditions within the ice were not recorded in this study so it is not possible to try to relate variations in faunal density between sampling dates to changes in their environment. One interesting finding was the similarity in the abundance trends exhibited by the three dominant copepod species (Figure 15). These species displayed the same relative changes in density throughout the study, suggesting that the same factor or factors might be affecting the populations in similar ways. Total copepod and amphipod abundance appeared to decline around 2 June. They might have been responding before other groups to changes in the ice associated with breakup. By 9 June, although the ice remained solid, there was a layer of low salinity (2.8 ppt) just below the water-ice interface, where no salinities lower than 28.9 ppt were recorded before (Figure 26).

There was a large amount of spatial variability in the ice fauna. Standard deviations were commonly greater than 50% of the mean for some taxa. Ice fauna apparently had a patchy distribution. Although determining the scale of aggregations was not a goal of this study, and the sampling program was not designed to examine this problem, it is evident that the size of faunal patches varied in the study area. Some pairs of cores were virtually identical in the abundance of each of the major taxa, and of copepod species. The patch size in these instances must have minimally been larger along one axis than twice the core diameter (21 cm). Other pairs of cores differed greatly, indicating that these patches were smaller. Patchiness of ice flora has been found to be correlated with light attenuation due to snow depth (Clasby et al., 1976). This could not have been a factor in deter-



Table 2. Densities of meiofauna sampled from underice habitats in different areas in the Beaufort Sea. Values are given in number per m<sup>2</sup>. A typical value for the sediments beneath the ice station is presented for comparison.

#### MEIOFAUNAL DENSITIES

	m <sup>2</sup> (ranges)	REFERENCE
EPONTIC:		
STEFANSSON SOUND	4,500- 8,000	CAREY & MONTAGNA, 1982
NARWHAL ISLAND	36,000 - 320,000	KERN & CAREY, 1983
CANADIAN ARCTIC	300 - 53,000	CROSS, 1982
BENTHIC:		
STEFANSSON SOUND	60,605,000	CAREY & MONTAGNA, 1982

mining the patchiness of the ice fauna in this study since the snow cover over the sampling site was of uniform thickness at any one time.

Life-history studies of offshore marine benthic copepods are rare, and most of the work has been done on harpacticoids living in tide pools (Fraser, 1936; Harris, 1973), in littoral sediments (Rae, 1967; Barnett, 1970; Lasker et al., 1970; Harris, 1972; Jewett and Feder, 1977; Fleeger, 1979; Feller, 1980a), and on algae (Hicks, 1977). These studies have shown that there are many reproductive patterns in harpacticoids, and that even closely related, sympatric species may have markedly different life-histories. Barnett (1970) investigated the life cycles of two congeneric species inhabiting the same mudflat and found that each species had a distinct life-history. Despite these variations, Hicks (1979) has shown that reproductive strategies of harpacticoid copepods tend to differ more between habitats than within habitats. He suggests that factors such as food resource availability and environmental stability are important in determining the evolution of specific life-history strategies. Therefore, it might be expected that copepods inhabiting the ephemeral ice environment would show a different life-history pattern from those of copepods studied elsewhere.

It is evident that Harpacticus sp. and Cyclopina gracilis have different life-history strategies (Figures 16 and 17, and Appendix II: Table 27). C. gracilis appears to reproduce continuously during the ice algal bloom. Gravid females were found on five of the nine sampling dates. Since the number collected on any sampling date tended to be low, it is possible that there were gravid females in the ice throughout the sampling period, but not collected on some occasions because of their low density. Egg sacs may also have been shaken loose before the samples were examined in the laboratory. Continuous recruitment to the population is also indicated by the presence of young copepodites on all sampling dates. The location of modes in the size-frequency distributions of C. gracilis was similar from 15 May to the end of the study (Figure 17). Fleeger (1979) gave size-frequency distributions of Enhydrosoma propinquum that showed a pattern of constant peak locations for an extended period. He suggested that the stable population structure was brought about by continuous recruitment of nauplii. Cyclopina gracilis has been found associated with macro-algae (Sars, 1918) and described as a phytophile (Ceccherelli, 1976). Its continual reproduction, at least while in the ice, fits the strategy of continual or protracted reproduction utilized by most phytal harpacticoids (Hicks, 1979).

Harpacticus sp. did not appear to reproduce in the ice. Since the sampling period coincided with the annual ice algal bloom (Homer and Schrader, 1981) when food resources are highest, the lack of gravid females is surprising. Pre-copulatory clasping, which is typical of harpacticoids, occurred among individuals collected on 26 May and 2 June. Fraser (1936) suggested that the clasping of females, usually copepodites, by adult males precedes spermatophore transfer. The reproductive cycle of Harpacticus sp. could be similar to that of some sediment-dwelling copepods. Jewett and Feder (1977) showed that Harpacticus uniremis around Port Valdez, Alaska had a single distinct reproductive period. Males clasped females most often in April and gravid individuals began to appear approximately nine months later. The intertidal copepod Platychelipus laophontoides had one generation per year and a distinct reproduction period with gravid females being absent for half of the year (Barnett, 1970).

No life-history data for Harpacticus sp. are available for the rest of the year so it is not possible to describe the complete life-history of the organisms. Mating evidently takes place on the ice since clasping, which precedes spermatophore transfer, was observed there. Data from other habitats suggest that Harpacticus sp. probably has one or two generations per year (Jewett and Feder, 1977). The inseminated females probably migrate to the bottom when the ice breaks up in late May or early June. It is not known whether copepods recolonize the ice immediately after it reforms around October or later in the ice season. Low densi-

ties of diatoms are present in the ice from its formation and through the winter until around April (Clasby et al., 1973), so little food is presumably available at that time. No Harpacticus sp. adults were present in the April and early May samples indicating that either colonization occurred shortly before by copepodites, or that gravid females had migrated to the ice earlier. There are two possible explanations as to how gravid females could colonize the ice during the winter, in the near-absence of food, resulting in the population structure observed in the samples. First, they may produce resting eggs that could overwinter in the ice. Overwintering resting eggs that hatch up to five months after being laid have been found in calanoid copepods (Grice and Gibson, 1975). Second, it has been shown that certain harpacticoids have nauplii that undergo delayed development (Coull and Dudley, 1976), which could enable some offspring to survive under limited food conditions. Delayed naupliar development might explain the sudden influx of early copepodites on 2 June unlike adults and copepodites. Nauplii of benthic harpacticoids cannot swim (Hauspie and Polk, 1973), so colonization of the ice could not be by nauplii unless they were advected to the ice from the sediments.

It is common for sex ratios to vary temporally in species of marine copepods (Moraitou-Apostolopoulou, 1972; Hicks, 1977). This was true for Harpacticus sp. and Cyclopina gracilis collected from the ice. There was a general trend in which the percentage of Harpacticus sp. females increased through the study. Since it appeared that the individuals belonged to a single season's production of offspring, males may mature earlier than females. Males reached sizes at which they could be sexed before females did, as indicated by the initial low percentage of females in the total sexable segment of the population. Earlier male maturation has been noted for Huntemania jadensis (Feller-, 1980a) and Harpacticus uniremis (Jewett and Feder, 1977). It is not possible to discuss the relative development rates of C. gracilis males and females since recruitment to the population appeared to be continuous; however, Smyly (1961) reported that the males of Cyclops leukarti, a freshwater cyclopoid, mature earlier than females. Females predominated early in the study when the population density was low. This has been found in other marine copepods (Moraitou-Apostolopoulou, 1972).

No life-history strategies unique to the ice environment are evident from the data collected in this study. These two copepod species are not very different in their reproductive activity from other copepods living on the bottom. Previous studies (Coull and Vernberg, 1975; Jewett and Feder, 1977) have shown that the dominant copepod species reproduce continuously, while, rare species in the same environment reproduce seasonally. This might also be true for ice copepods where the dominant species, Cyclopina gracilis, was found to reproduce continuously throughout the study, while the less abundant Harpacticus sp. showed seasonal reproduction.

It is not possible to describe the complete life-history of any species when sampling takes place only during one season. The ice scraper samples were used to extend the sampling period as much as possible, even though these samples were taken outside of the study area. The size-frequency distributions of Harpacticus Sp. and Cyclopina gracilis in these samples generally fit the trends exhibited in the cores. The only exception to this agreement is with the size-frequency distribution of C. gracilis on 14 April. The population appear to be more mature in this sample than in those collected on 24 April. Small-scale spatial heterogeneity in the population size-structures of benthic organisms has previously been observed (Curtis and Peterson, 1977), and may explain the apparent discrepancy in the size-frequency distributions between 14 April and 24 April. Sampling throughout the year, in the ice when the animals are there, and on the bottom when they inhabit the sediments, is required to fully describe the life-history strategies of these organisms.

This study has shown that frequent sampling is required to observe changes in the population structure of meiofauna. Significant changes in the size-frequency

distributions for the two dominant ice copepods occurred on time scales of less than one week. Size-frequency distributions have previously been employed to study copepod life-histories (Lasker et al., 1970; Jewett and Feder, 1977; Fleeger, 1979), but not with samples taken as frequently as in this study. Many copepod species can undergo complete development in the lab, from hatch to hatch, in less than 30 days (Rosenfield and Coull, 1974), so frequent samples must be taken to observe the rapid changes in the populations. Feller (1980b) observed that the lengths of some copepodite stages of Huntemania jadensis overlapped. Although this was true to some extent for both ice species studied, the utilization of size-frequency distribution provided useful information in less time than would be required to identify each copepodite to its stage.

With the objective of determining the source of the ice meiofauna at Narwhal Island, scrapings were made of macro-algae in Stefansson sound. The cyclopoid copepod Cyclopina gracilis has been reported as epiphytic (Sars, 1918), and the macro-algae at the Boulder Patch (Dunton et al., 1982) could be the source of this species for colonization of the ice undersurface. No C. gracilis were collected from the sediments at the Stefansson Sound Ice Station (Carey and Montagna, 1982). Though cyclopoid copepods were present in the algal scrapings, no specimens of C. gracilis were found (Table 3). This species was collected near the bottom (Homer and Schrader, 1981), and thus may be plankto-benthic in existence.

Table 3. Copepods and nematodes from scrapings of macro-algae fronds at the Stefansson Sound ice station (SS). Collections made in 1981.

Scrapings	Algae	Cyclopoid/Harpacticoid	Calanoid	Nematodes	<u>Cyclopina gracilis</u>
1	Red	243	1	+	No
2	Brown	25	14	+	No
3	Red	125	1	+	No
4	Brown	24	12	+	No
5	Red	11	5	+	No
6	Brown	32	9	+	No
7	Brown	36	3	0	No
8	Red	151	4	+	No
9	Red	58	2	+	No
10	Brown	50	8	+	No

### C. Particle flux to sediments (Narwhal Island)

Various workers have conjectured that the ice biotic assemblage is an early source for the arctic ecosystem and that there should be a pulse of downward organic flux during ice melt and break-up (Alexander, 1980, 1981; Golikov and Scarlato, 1973; Homer and Schrader, 1982). Our data suggest that this community does provide an early source of food for the benthos. The fluxes of organic carbon are relatively high even at the time of the first collection toward the end of April. However, the lack of temporal trends does not support the hypothesis that there is a sudden pulse of particle flux during ice melting. It is possible, however, that field activities had to be curtailed before such an event took place. Divers' observations indicate that the ice algal layer had almost entirely disappeared at the time of the last particle trap deployment. It was also noted that turbidity in the water column was high, perhaps caused by the ice algal cells released from the ice. Therefore, downward transport of this material is slower than anticipated. Results from Pett et al. (1983) also support this conclusion; results from the Canadian Beaufort Sea did not demonstrate a pulses of organic flux during ice melt.

## VIII. Conclusions

- A. Benthic continental shelf fauna: cross-shelf trends
  1. The **macrobenthos** are most abundant numerically nearshore, while their biomass peaks at the shelf edge and upper continental slope.
  2. The megabenthos are most abundant on the outer shelf and upper level of the continental slope.
  3. The major part of the community causing the increased densities and standing stocks are **polychaete** worms (Minuspio cirrifera) for the macrofauna and several species of Ophiuroidea for the megafauna.
  4. Species richness for the **polychaetous** annelids and bivalve molluscs is highest on the inner continental shelf. This contrast to temperate patterns is hypothesized to be caused by low wave turbulence in the Arctic.
  5. The higher **benthic** numerical densities and standing stocks in the SW Beaufort Sea are similar to levels found in rich temperate marine environments.
- B. Ice fauna (Narwhal Island)
  1. Large densities of several invertebrate taxa, most notably nematodes, **copepods**, and **turbellarians**, were present in the fast ice of the Beaufort Sea in 1980. Although the density of the ice fauna was low compared to what is typically found in sediments, it was much greater than had previously been reported from the ice.
  2. The life-histories of two **copepods**, Cyclopina gracilis and Harpacticus sp., while inhabiting the ice are similar to the life-histories of exclusively benthic copepods. The ice species were different from each other in terms of their life-histories, so it appears that there is not a life-history strategy unique to the ice. If this is the case, it is surprising that more species do not utilize the ice environment.
  3. The midwater and underice samples indicate that the harpacticoid and cyclopoid copepods leave the ice during the rapid salinity decrease in early June and are then present midwater. The hypothesis that they migrate (fall?) to the bottom is being tested.
  4. Five species of gammarid amphipods form the ice macrofaunal assemblage (99.3%) on the inner shelf in the SW Beaufort Sea.
  5. A normally benthic species, Pseudalibrotus (=Onisimus) litoralis, dominates the assemblage and feeds, grows and releases young at the ice under-surface.
  6. The midwater collections of **gammarid** amphipods suggest a frequent interchange between the **benthic** and epontic populations with a diurnal maxima between 0100-0300 hrs, and a seasonal increase in activity in early April and early June.
  7. The ice biotic community is hypothesized to be a feeding ground for amphipod juveniles.
  8. The ice substrate and ice algae in the arctic provide an alternate environment and an early food source to a mixture of pelagic and benthic gammarid amphipod species.
  9. It is hypothesized that the **benthic** gammarid amphipod, P. litoralis, migrates to the bottom layer in the season with two environmental cues: reduced salinities and the onset of dark periods during the arctic summer.

C \*Particle flux

1. The particulate carbon and nitrogen flux to the sediments was relatively high during the entire study period.
2. There was no major increase in flux of particulate organic matter to the sediments during the melting season.
3. Fecal pellets from 2 crustacean species were among the few recognizable large particles; their fluxes varied during the study period.
4. Fecal pellets attributed to P. littoralis demonstrate that this species is feeding directly upon the underice diatom assemblage.
5. Though the fluxes to arctic shallow water sediments are low compared to rich temperate environments, the ice diatom assemblage is likely to be the earliest source of new carbon to the arctic ecosystem.

## IX. Needs for further study

Though general and some specific patterns of distribution and abundance of the benthic invertebrate fauna have been determined from the inner continental shelf to the upper slope, much remains to be accomplished in three main areas of research: (1) food web, (2) ice fauna, and (3) biological rates.

### A. Food web

Offshore of the barrier islands the continental shelf benthic food web is poorly defined. The food habitats of large predators such as demersal fishes, seabirds and marine mammals that feed on the benthos are not well known. Offshore populations of adult arctic cod have not been well-studied, and their food sources are not known. Data from inshore waters indicate that epibenthic animals, particularly mysids and amphipods, are pivotal food web links and that the infaunal invertebrates are not important in the oceanic food web (Griffiths and Dillinger, 1981). This hypothesis should be extensively tested to define the role of the benthos in the ecosystem. It is possible that there are few higher predators on the Beaufort Sea infauna; therefore, larger stocks of benthos may exist, e.g., at the shelf edge and upper slope.

The role of the sea ice algal blooms in the benthic (and pelagic) food web remains not well known. The carbon input to the ecosystem by this community is not known, nor are the vertical fluxes through which the ice community and the benthic community would interact. Data from other studies (RU #537 and 467) indicate that ice algal blooms are present on the undersurface of the sea ice out to at least 100 n.m. from shore, so this carbon source may be important over large areas.

### B. Ice fauna

Though initial description of the invertebrate sea ice assemblage has been achieved in nearshore waters beyond the barrier islands, there is a basic lack of knowledge about the ice fauna and its relationship to the benthos and pelagic fauna beneath. Nor do we know the areal extent and patchiness of the ice fauna and its relationship to ice as a substrate--with or without a food source at the ice-water interface. The ice may act as a concentrating interface for advanced and metamorphosing larval stages of benthic invertebrate fauna because it is a solid substrate--albeit upside down. Further offshore in the polar pack where the bottom drops away in deeper water, are there macrofaunal grazers primarily from the water column associated with the ice? Are there benthic meiofauna that exist as permanent members of the ice assemblage? And what is the food web associated with the sea ice in this environment?

### C. Biological rates

Much basic information is needed on biological rates--reproductive, growth, mortality, recolonization and metabolic for the purpose of determining the biological activity of the arctic fauna. What are the turnover rates of the benthos (production/biomass) beyond the barrier islands; are the secondary production rates lower than in more temperate environments? Knowledge of the recolonization rates pertain directly to the ability of the fauna, particularly the important mysid and amphipod crustaceans, to recover after a natural or pollution disturbance event. This information would be most useful in modelling food web recovery rates of a region of the inner shelf of the Beaufort Sea after a major oil spill.



## X. Auxiliary Material

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**B. Papers in preparation or in print**

These papers and manuscripts listed below are totally or partially derived from OCSEAP **subprojects** by RU #006 covered in this Final Report.

**1. In print**

Kern, J. C. and A. G. Carey, Jr. 1983. The **faunal** assemblage inhabiting seasonal sea ice in the nearshore Arctic Ocean with emphasis on the **copepods**. Mar. **Ecol. Progr. Ser.** **10:159-167.**

Carey, A. G., Jr., P. H. Scott and K. R. Walters. 1984. Distributional ecology of shallow **SW Beaufort Sea** (Alaska) bivalve **Mollusca**. Mar. **Ecol. Progr. Ser.** **17(2).**

**2. In press**

Carey, A. G., Jr. Marine ice fauna: Arctic. **In:** R. A. Homer (Ed.), Ice **Biota**. CRC Press, Boca Raton.

**3. In preparation**

Boudrias, M. A. and A. G. Carey, Jr. Life-history strategy and feeding ecology **fo Pseudalibrotus (=Onisimus) litoralis** (Crustacea: Amphipoda): An **underice** population of the SW Beaufort Sea. **Ophelia**.

Carey, A. G., Jr. Cross-shelf trends in the southeastern Beaufort Sea: **macrobenthos** and **megabenthos**. Polar Biology.

Carey, A. G., Jr., R. E. Ruff and K. R. Walters. Community ecology of shallow SW Beaufort Sea **Polychaeta (Annelida)**. Coastal and Estuarine Science.

**C. Oral Presentations**

- 1.** The distribution and abundance of **benthic macrofauna** and megafauna across the northern Alaska shelf and upper slope of the SW Beaufort Sea. **ASLO Annual Mtng.** North Carolina State Univ., June 1982.
- 2.** Shallow southwest Beaufort Sea (Alaska) ice **macrofauna**: Interactions with the **epibenthic** community., **ASLO/AGU Meeting**, San Francisco, CA, December 1982.
- 3\*** The structure source and ecology of **underice** fauna assemblages. **Benthic Ecology Meetings**. Melbourne, FL, March 1983.
- 4.** Particle and **faunal** fluxes between the sea ice and **benthic** environments in the shallow SW Beaufort Sea (Alaska). Western Society of Naturalists Annual Meeting, **Burnaby, B.C.**, December 1983.

Appendix I. Pingok Island Cross-Shelf Transect Data.



Table 4. Cross-shelf trends **macrofauna** station collection information (PIB = Pingok Island Benthos, R/V ALUMIAK cruise; WBS = Western Beaufort Sea WEBSEC cruise, USCGC GLACIER).

<u>Depth</u>	<u>Station</u>	<u>Replicates</u>	<u>Position</u>	<u>Date</u>
5 m	PIB-5	5	70°34.9'N 149°32.0'W	22 Aug 1976
10 m	PIB-10	5	70°34.8'N 149°32.3'W	22 Aug 1976
15 m	PIB-15	5	70°38.2'N 149°34.6'W	24 Aug 1976
23 m	WBS-30 CG-63	5	70°43'N 149°00'W	7 Sept 1971
47 m	WBS-23 CG-44	5	71°01'N 148°22'W	31 Aug 1971
100 m	WBS-20 CG-30	5	71°00'N 147°57'W	30 Aug 1971
200 m	WBS-41 CG-83	5	71°12.2'N 149°44.8'W	11 Sept 1971
360 m	WBS-19 CG-29	5	71°08.7'N 148°00.5'W	29 Aug 1971
700 m	WBS-27 CG-58	5	71°14.5'N 149°25.5'W	5 Sept 1971
1800 m	WBS-26 CG-57	5	71°21.3'N 149°32'W	4 Sept 1971

Table 5. Cross-shelf trends otter **trawl** station locations for **mega-epifauna**.

<u>Station</u>	<u>Position</u>	<u>Depth</u>	<u>Date</u>	<u>Tow Duration</u>
WBS-25 CG-56	71°12'N 148°35'W	360 m	3 Sept 1971	10 min.
WBS-31 CG-65	70°43'N 149°02'W	30 m	6 Sept 1971	15 min.
WBS-32 CG-66	70°43'N 149°06'W	31 m	7 Sept 1971	5 min.
WBS-21 CG-36	71°11.3'N 148°31.9'W	159 m	18 Aug 1972	30 min.
WBS-22 CG-37	71°05.7'N 148°41'W	55 m	19 Aug 1972	15 min.
WBS-27 CG-43	70°59.5'N 149°33.8'W	29 m	22 Aug 1972	10 min.

Table 6. Cross-shelf trends bottom stereo photograph station locations for visible **benthic mega-epifauna**.

<u>Station</u>	<u>Position</u>	<u>Depth</u>	<u>Date</u>	<u>Total Area</u>
WBS-30 CG-47	70°50'N 150°0.9'W	25 m	23 Aug 1972	22.17 m <sup>2</sup>
WBS-32 CG-49	71°11.5'N 150°00'W	44 m	24 Aug 1972	115.4 m <sup>2</sup>
WBS-33 CG-50	71°12.4'N 150°02.6'W	80 m	25 Aug 1972	52.30 m <sup>2</sup>
WBS-35 CG-52	71°17'N 150°05'W	750 m	26 Aug 1972	103.05 m <sup>2</sup>
WBS-36 CG-53	71°35.9'N 150°01.9'W	2160 m	27 Aug 1972	20.88 m <sup>2</sup>
WBS-46 CG-75	71°12.3'N 149°43'W	195 m	9 Sept 1972	48.37 m <sup>2</sup>

Table 7. Animal densities for station PIB-5 per 0.1  $\square$  2, collected on 22 August 1976.

Phylum	Class	Order	Grab Number					Total per m <sup>2</sup> fauna	% of fauna
			1419	1420	1421	1423	1424		
Nematoda			<b>1</b>	--	<b>2</b>	<b>1</b>	4	16	1.2
Nemertinea			<b>1</b>	2	3	--	.-	12	0.9
<b>Annelida:</b>	<b>Polychaeta</b>		71	110	104	<b>112</b>	<b>176</b>	1146	<b>87.2</b>
<b>Priapulida</b>			4	5	7	3	2	42	<b>3.2</b>
Arthropoda:	Crustacea:	Amphipoda	17	5	2	4	4	64	4.9
		Isopoda	--	1	<b>1</b> <b>1</b>	2	--	8	0.6
		Cumacea	<b>1</b>	--	1	6	--	16	<b>1.2</b>
<b>Mollusca:</b>	<b>Pelecypoda</b>		2	--	1	.-	2	10	0.8
TOTAL			96	123	119	127	184	1314	100.0

Table 8. Animal densities for station PIB-10 per 0.1 m<sup>2</sup>, collected on 22 August 1976.

Phylum	Class	Order	Grab Number					Total per m <sup>2</sup> fauna	% of fauna
			1425	<b>1426</b>	1427	1429	1430		
Nematoda			2	8	<b>33</b>	30	12	<b>170</b>	<b>2.3</b>
<b>Annelida:</b>	<b>Polychaeta</b>		475	683	<b>606</b>	436	860	6120	<b>82.9</b>
<b>Priapulida</b>			1	<b>1</b>	4	7	--	26	0.4
Arthropoda:	Crustacea:	Amphipoda	--	<b>1</b>	<b>1</b>	21	3	52	0.7
		Harpacticoida	--	--	<b>6</b>	--	--	12	0.2
		Isopoda	2	--	<b>1</b>	--	4	14	0.2
		Ostracoda	--	16	17	6	--	78	<b>1.1</b>
		Tanaidacea	--	--	1	4	<b>1</b>	12	0.2
		Cumacea	1	<b>2</b>	2	4	<b>3</b>	24	0.3
<b>Mollusca:</b>	<b>Pelecypoda</b>		39	<b>67</b>	<b>109</b>	<b>104</b>	101	<b>840</b>	11.4
	Gastropoda		--	6	6	3	3	36	0.5
TOTAL			518	776	747	585	975	7384	100.0

Table 9. Animal densities for station PIB-15 per 0.1  $\square$  2, collected on 22 August 1976,

Phylum	Class	Order	Grab Number					Total per m <sup>2</sup> fauna	% of fauna
			1432	1433	1434	1435	1436		
Cnidaria:	Anthozoa		2	1	1	--	--	8	0.4
Nematoda			--	1	2	2	--	10	0.5
Nemerthinea			--	3	3	1	3	20	1.1
<b>Annelida:</b>	<b>Polychaeta</b>		53	73	86	107	83	804	42.2
Priapulida			--	--	--	--	1	2	0.1
Arthropoda:	<b>Crustacea:</b>	Amphipoda	4	9	17	12	14	112	5.9
		Isopoda	--	--	3	1	1	10	0.5
		Ostracoda	--	--	4	2	--	12	0.6
		Tanaidacea	--	--	7	--	--	14	0.7
		Cumacea	8	4	1	14	3	60	3.2
	Pycnogonida		--	--	--	--	1	2	0.1
<b>Mollusca:</b>	<b>Pelecypoda</b>		25	53	31	53	58	440	23.1
	Gastropoda		5	3	1	7	7	46	2.4
Echinoderms ta:	<b>Holothuroidea</b>		2	3	2	1	--	16	0.8
Hemichordata			1	--	--	--	--	2	0.1
<b>Chordata:</b>	Ascidacea		10	47	60	16	40	346	18.2
<b>TOTAL</b>			110	196	216	214	211	1904	100.0

Table 10. Relative abundance of major macrofauna taxa (>1.0 mm) on the cross-shelf transect.

	PIB-5 5 m		PIB-10 10 m		PIB-15 15 m	
Cidaria: Anthozoa	--		--		4	0.4%
Annelida: Oligochaeta	--		--		--	
Polychaeta	573	88.3%	3060	85.0%	402	42.4%
Arthropoda: Amphipoda	32	4.9%	26	0.7%	56	5.9%
Isopoda	4	0.6%	7	0.2%	5	0.5%
Cumacea	8	1.2%	12	0.3%	30	3.2%
Ostracoda	--		39	1.1%	6	0.6%
Tanaidacea	--		6	0.2%	7	0.7%
Pycnogonida	--		--		1	0.1%
Mollusca: Pelecypoda	5	0.8%	420	11.7%	220	23.2%
Gastropoda	--		18	0.5%	23	2.4%
Echinodermata: Ophiuroidea	--		--		--	
Holothuroidea	--		--	8		0.8%
Chordata: Ascidiacea	--		--		173	18.2%
Others (Priapulida, Hemichordata, Nemertinea)	27	4.2%	13	0.4%	12	1.3%
Total	649		3601		949	

Table 10. con't.

	WBS 30 CG63 23 m		WBS 23 CG44 47 m		WBS 20 GC30 100 m		WBS 41 GC83 200 m	
Cnidaria: Anthozoa	--		1	0.1%	--		17	1.1%
Annelida: Oligochaeta	--		--		--		--	
Polychaeta	318	40.8%	520	42.4%	365	30.8%	1273	85.2%
Arthropoda: Amphipoda	10	1.3%	387	28.4%	83	7.0%	47	3.1%
Isopoda	1	0.1%	14	1.1%	--		--	
Cumacea	19	2.4%	40	3.3%	14	1.2%	6	0.4%
Ostracoda	--		93	7.6%	193	16.3%	7	0.5%
Tanaidacea	5	0.6%	26	2.1%	50	4.2%	1	0.1%
Pycnogonida	--		2	0.2%	--		--	
Mollusca: Pelecypoda	274	35.2%	158	12.9%	413	34.9%	78	5.2%
Gastropoda	132	16.9%	6	0.5%	15	1.3%	6	0.4%
Echinodermata: Ophiuroidea	16	2.1%	6	0.5%	37	3.1%	46	3.1%
Holothuroidea	3	0.4%	4	0.3%	--		--	
Chordata: Ascidiacea	--		--		7	0.6%	--	
Others (Echiuroidea, Sipuncula, Aplacophora, Brachiopoda, Priapulida, Nemertinea)	1	0.1%	8	0.7%	8	0.7%	13	0.9%
Total	799		1226		1185		1494	

Table 10. con't.

	WBS 19 CG 29 360 m		WBS 27 GC 58 700 m		WBS 26 CG 57 1800 m	
Cnidaria: Anthozoa	--		--		--	
Annelida: Oligochaeta	--		154	6.8%	--	
Polychaeta	1031	87.3%	1611	70.9%	263	39.1%
Arthropoda: Amphipoda	19	1.6%	36	1.6%	15	2.2%
Isopoda	--		3	0.1%	6	0.9%
Cumacea	3	0.3%	12	0.5%	21	3.1%
Ostracoda	62	5.2%	67	2.9%	3	0.4%
Tanaidacea	8	0.7%	57	2.5%	27	4.0%
Pycnogonida	--		3	0.1%		
Mollusca: Pelecypoda	40	3.4%	295	13.0%	320	47.5%
Gastropoda	2	0.2%	14	0.6%	1	0.1%
Echinodermata: Ophiuroidea	10	0.8%	6	0.3%	4	0.6%
Holothuroidea	--		--		5	0.7%
Chordata: Ascidiacea	--				--	
Others (Aplacophora, Sipuncula, Scaphopoda)	6	0.5%	15	0.7%	8	1.2%
Total	1181		2273		673	

Table 11. Biomass, preserved wet weight in grams per 0.1 m<sup>2</sup> from station PIB-5 (OCS-5), collected on 22 August 1976.

Group	Grab Number					Total weight per m <sup>2</sup>	% of biomass
	1419	1420	1421	1423	1424		
<b>Anthozoa</b>							
<b>Sipuncula</b>							
<b>Annelida</b>	.58	.60	.49	.84	1.16	7.34	83.2
Arthropoda	.03	.47	.06	.05	.02	1.26	14.3
<b>Mollusca</b>	.03	-	.01	-	+	.08	0.9
<b>Echinodermata</b>	-	-	+				
Misc. Phyla	.01	.02	.02	.02	+	.14	1.6
<b>TOTAL</b>	.65	1.09	.58	.91	1.18	8.82	100.0

+ = presence, not weighable

- = absence

Table 12. Biomass, preserved wet weight in grams per 0.1 m<sup>2</sup> from station PIB-10 (OCS-5), collected on 22 August 1976.

Group	Grab Number					Total weight per m <sup>2</sup>	% of biomass
	1425	1426	1427	1429	1430		
<b>Anthozoa</b>							
<b>Sipuncula</b>							
<b>Annelida</b>	.87	.78	.87	.77	1.20	8.98	50.7
Arthropoda	.04	.04	.03	.07	.12	.60	3.4
<b>Mollusca</b>	.19	-	1.90	1.12	.70	7.82	44.2
<b>Echinodermata</b>	+	-	-	-	-		-
Misc. Phyla	.07	.01	.04	.02	.01	.30	1.7
<b>TOTAL</b>	1.17	.87	2.84	1.98	2.03	17.70	100.0

+ = presence, not weighable

- = absence

Table 13. Biomass, preserved wet weight in grams per 0.1 m<sup>2</sup> from station PIB-15 (ocs-5), collected on 22 August 1976.

Group	Grab Number					Total weight per m <sup>2</sup>	% of biomass
	1432	1433	1434	1435	1436		
Anthozoa							
Sipuncula							
Annelida	1.92	3.65	1.20	1.12	.61	17.00	12.8
Arthropoda	.29	.13	.07	.18	.19	1.72	1.3
Mollusca	4.71	10.24	5.10	9.21	11.44	81.40	61.6
Echinodermata	.02	.12	.04	.08	-	.52	.4
Misc. Phyla	.74	2.73	5.87	3.27	3.19	31.60	23.9
TOTAL	7.68	16.87	12.28	13.86	15.43	132.24	100.0

- = absence



Table 14. SW Beaufort Sea Cross-Shelf Transect Polychaete species distribution.

Polychaete Species			
Depth	No/m*	Name	Rank
5 m	524	<b>Minuspio cirrifera</b>	<b>1</b>
	310	Ampharete vega	2
	110	<b>Marenzelleria wireni</b>	3
	60	Chone <u>nr.</u> C. murmanica	4
	32	Tharyx ?acutus	5
	30	Capitella capitata	6
	26	Sphaerodoropsis minuta	7
	14	Eteone longis	8
	6	<b>Scoloplos armiger</b>	9.5
	6	Sphaerodoridium sp. A	9.5
	4	<b>Orbinia sp.</b>	
	2	Micronephthys minuta	
	2	<b>Onuphis quadricuspis</b>	
	2	Paramphitrite tetrabanchia	
	2	<b>Terebellides stroemi</b>	
10 m	4688	<b>Minuspio cirrifera</b>	1
	412	Chone <u>nr.</u> C. murmanica	2
	234	<b>Sphaerodoropsis minuta</b>	3
	144	Tharyx ?acutus	4
	84	Micronephthys minuta	5
	78	<b>Cossura longocirrata</b>	6
	46	Capitella capitata	7.5
	46	Eteone longa	7.5
	20	Sphaerodoridium sp. A	9
	18	Ampharete vega	10
	14	<b>Aricidea</b> (Allis) cf. A. suecica	
	14	<b>Ophryotrocha sp.</b>	
	14	Sternaspis scutata	
	12	<b>Terebellides stroemi</b>	
	10	<b>Marenzelleria wireni</b>	
	6	Parheteromastus sp. A	
	2	<b>Euchone analis</b>	
	2	Heteromastus filiformis	
	2	Mystides borealis	
	2	Nephtys ciliata	
	2	Paramphitrite tetrabanchia	
	2	<b>Praxillella praetermissa</b>	
	2	<b>Scalibregma inflatum</b>	

Table 14. con't.

Depth	No/m <sup>2</sup>	Name	Rank
15 m	182	<i>Praxillella praetermissa</i>	1
	60	<i>Tharyx ?acutus</i>	2
	56	<i>Pholoe minuta</i>	3
	48	<i>Chaetozone setosa</i>	4
	46	<i>Minuspio cirrifera</i>	5
	42	<i>Scoloplos acutus</i>	6
	40	<i>Clymenura polaris</i>	7
	26	<i>Marenzelleria wireni</i>	8.5
	26	<i>Micronephthys</i> <i>minuta</i>	8.5
	24	<i>Microclymene</i> sp.	10
	20	<i>Ampharete acutifrons</i>	
	18	<i>Nereimyra aphroditoides</i>	
	14	<i>Brada villosa</i>	
	14	<i>Hesionidae</i> gen. et sp. nov.	
	12	<i>Eteone longis</i>	
	12	<i>Euchone papillosa</i>	
	10	<i>Laonome kroeyeri</i>	
	10	<i>Scalibregma inflatum</i>	
	8	<i>Capitella capitata</i>	
	8	<i>Lysippe labiata</i>	
	8	<i>Scoloplos armiger</i>	
	8	<i>Sternaspis scutata</i>	
	6	<i>Amphicteis sundevalli</i>	
	6	<i>Anaitides groenlandica</i>	
	6	<i>Antinoella sarsi</i>	
	6	<i>Nephtys ciliata</i>	
	6	<i>Ophelina cylindrica</i> <i>audatus</i>	
	6	<i>Polydora socialis</i>	
	6	<i>Sabellides borealis</i>	
	6	<i>Schistomeringos caeca</i>	
	4	<i>Aricidea</i> (Allis) <i>cf.</i> <i>A. suecica</i>	
	4	<i>Heteromastus filiformis</i>	
	4	<i>Nephtys longosetosa</i>	
	4	<i>Levinsenia gracilis</i>	
	4	<i>Terebellides stroemi</i>	
	2	<i>Aricidea</i> (Allis) sp. C	
	2	<i>Apistobanchus tullbergi</i>	
	2	<i>Dexiospira spirillum</i>	
	2	<i>Diplocirrus longisetosus</i>	
	2	<i>Dysponetus</i> sp. nov.	
	2	<i>Euchone analis</i>	
	2	<i>Euchone elegans</i>	
	2	<i>Euchone</i> sp.	
	2	<i>Fabricinae</i>	
	2	<i>Lanassa venusta</i>	
	2	<i>Melaenis loveni</i>	
	2	<i>Prionospio steenstrup</i>	
	2	<i>Sphaerodoridium</i> sp. A	

Table 14. con't.

Depth	No/m <sup>2</sup>	Name	Rank
23 m	348	<i>Capitella capitata</i>	1
	244	<i>Tharyx ?acutus</i>	2
	180	<i>Chone</i> <u>nr.</u> <i>C. murmanica</i>	3
	148	<i>Minuspio cirrifera</i>	4
	114	<i>Pholoe minuta</i>	5
	106	<i>Heteromastus filiformis</i>	6
	56	<i>Sternaspis scutata</i>	7
	46	<i>Paramphitrite tetrabanchia</i>	8
	42	<i>Cossura longocirrata</i>	9
	40	<i>Ophelina cylindricaudatus</i>	10
	34	<i>Lumbrineris minuta</i>	
	32	<i>Lysippe labiata</i>	
	28	<i>Aricidea</i> (Allis) <u>cf.</u> <i>A. suecica</i>	
	26	<i>Chaetozone setosa</i>	
	24	<i>Parheteromastus</i> sp. A	
	18	<i>Scoloplos acutus</i>	
	16	<i>Clymenura polaris</i>	
	14	<i>Prionospio steenstrupi</i>	
	12	<i>Praxillella praetermissa</i>	
	12	<i>Terebellides stroemi</i>	
	10	<i>Brada villosa</i>	
	10	<i>Eteone longs</i>	
	8	<i>Antinoella sarsi</i>	
	8	<i>Lumbrineris fragilis</i>	
	8	<i>Lumbrineris impatiens</i>	
	8	<i>Micronephthys minuta</i>	
	8	<i>Proclea graffii</i>	
	8	<i>Spirorbis granulates</i>	
	6	<i>Ampharete acutifrons</i>	
	6	<i>Schistomeringos caeca</i>	
	4	<i>Anaitides groenlandica</i>	
	4	<i>Cistenides hyperborea</i>	
	4	<i>Eteone flava</i>	
	4	<i>Nephtys ciliata</i>	
	2	<i>Aglaophamus malmgreni</i>	
	2	<i>Apistobanchus tullbergi</i>	
	2	<i>Chone duneri</i>	
	2	<i>Dexiospira spirillum</i>	
	2	<i>Lagisca extenuata</i>	
	2	<i>Scalibregma inflatum</i>	
	2	<i>Sphaerodoropsis minuta</i>	
	2	<i>Trochochaeta carica</i>	
	2	<i>Typosyllis cornuta</i>	

Table 14. con't.

Depth	No/m <sup>2</sup>	Name	Rank
47 m	556	Chone <u>nr.</u> C. murmanica	1
	284	Tharyx ?acutus	2
	244	Chaetozone setosa	3
	194	Lumbrineris minuta	4
	168	Aricidea (Allis) <u>cf.</u> A. suecica	5
	116	Nereimyra aphroditoides	6
	104	Ophelina cylindricaudatus	7
	98	Prionospio steenstrupi	8
	94	Terebellides stroemi	9
	78	Pholoe minuta	10
	74	Micronephthys minuta	
	70	Heteromastus filiformis	
	60	Exogone naidina	
	60	Parheteromastus sp. A	
	54	Barantolla sp.	
	50	Nereis zonata	
	44	Ampharete acutifrons	
	40	Lysippe labiata	
	22	Laphania boeckii	
	22	Maldane sarsi	
	20	Spirorbis granulates	
	20	Typosyllis cornuta	
	18	Minuspio cirrifera	
	16	Ampharete arctica	
	16	Lumbrineris fragilis	
	16	Scoloplos acutus	
	14	Laonice cirrata	
	12	Antinoella sarsi	
	12	Paraonis sp. A	
	10	Autolytus fallax	
	10	Lagisca extenuata	
	8	Chone duneri	
	8	Clymenura polaris	
	8	Eteone longa	
	8	Polycirrus medusa	
	6	Gattyana cirrosa	
	6	Onuphis quadricuspis	
	4	Amphicteis gunneri	
	4	Cirratulus cirratus	
	4	Diplocirrus longisetosus	
	4	Melinna elisabethae	
	4	Polydora caulleryi	
	4	Levinsenia gracilis	
	2	Apistobranchus tullbergi	
	2	Artacama proboscidea	
	2	Brada nuda	
	2	Brada villosa	
	2	Chone infundibuliformis	
	2	Diplocirrus hirsutus	
	2	Lanassa venusta	

2	<b>Myriochele</b> heeri
2	<b>Nephtys</b> ciliata
2	<b>Nephtys</b> paradoxa
2	<b>Ophelina</b> acuminata
2	<b>Paramphitrite</b> tetrabanchia
2	<b>Praxillella</b> praetermissa
2	<b>Schistomeringos</b> caeca
2	<b>Sphaerodoridium</b> biserialis
2	<b>Sphaerodoridium</b> sp. A

Table 14. con't.

Depth	No/m <sup>2</sup>	Name	Rank
100 m	178	<i>Spiochaetopterus typicus</i>	1
	136	<i>Micronephthys minuta</i>	2
	104	<i>Chone</i> nr. <i>C. murmanica</i>	3
	94	<i>Tharyx</i> ? <i>acutus</i>	4
	92	<i>Lysippe labiata</i>	5
	84	<i>Lumbrineris minuta</i>	6
	78	<i>Terebellides stroemi</i>	7
	56	<i>Laonice cirrata</i>	8
	44	<i>Ophelina cylindrica</i> <i>audatus</i>	9*5
	44	<i>Levinsenia gracilis</i>	9.5
	40	<i>Maldane sarsi</i>	
	32	<i>Pholoe minuta</i>	
	28	<i>Cossura longocirrata</i>	
	28	<i>Minuspio cirrifera</i>	
	24	<i>Clymenura polaris</i>	
	24	<i>Scoloplos acutus</i>	
	20	<i>Aricidea</i> (Allis) cf. <i>A. suecica</i>	
	18	<i>Myriochele heeri</i>	
	14	<i>Parheteromastus</i> sp. A	
	12	<i>Barantolla</i> sp.	
	12	<i>Heteromastus filiformis</i>	
	10	<i>Sternaspis scutata</i>	
	8	<i>Lagisca extenuata</i>	
	8	<i>Laphania boeckii</i>	
	6	<i>Apistobanchus tullbergi</i>	
	6	<i>Chaetozone setosa</i>	
	6	<i>Exogone naidina</i>	
	6	<i>Glyphanostomum pallescens</i>	
	4	<i>Ampharete arctica</i>	
	4	<i>Antinoella sarsi</i>	
	4	<i>Lumbrineris impatiens</i>	
	4	<i>Scalibregma inflatum</i>	
	4	<i>Sphaerodorum gracilis</i>	
	4	<i>Typosyllis cornuta</i>	
	2	<i>Axionice flexuosa</i>	
	2	<i>Eteone longis</i>	
	2	<i>Euchone papillosa</i>	
	2	<i>Gattyana cirrosa</i>	
	2	<i>Lanassa venusta</i>	
	2	<i>Lumbrineris fragilis</i>	
	2	<i>Melinna elisabethae</i>	
	2	<i>Nephtys ciliata</i>	
	2	<i>Onuphis quadricuspid</i>	
	2	<i>Paraonis</i> sp. A	
	2	<i>Polydora caulleryi</i>	
	2	<i>Schistomeringos caeca</i>	
	2	<i>Sphaerodoropsis biserialis</i>	
	2	<i>Trochochaeta carica</i>	

Table 14. con't.

Depth	No/m*	Name	Rank
200 m	814	Tharyx ?acutus	1
	604	Micronephthys minuta	2
	360	Scolopos acutus	3
	336	Aricidea (Allis) cf. A. suecica	4
	246	Levinsenia gracilis	5
	200	Cossura longocirrata	6
	196	Lumbrineris minuta	7
	172	Chaetozone setosa	8
	112	Prionospio steenstrupi	9
	50	Lysippe labiata	10
	44	Terebellides stroemi	
	36	Eteone longs	
	30	Nephtys ciliata	
	30	Proclea graffii	
	22	Barantolla sp.	
	22	Spiochaetopterus typicus	
	10	Artacama proboscidea	
	8	Antinoella sarsi	
	8	Heteromastus filiformis	
	8	Laphania boeckii	
	8	Myriochele heeri	
	8	Onuphis quadricuspis	
	6	Maldane sarsi	
	4	Anaitides groenlandica	
	4	Nereimyra aphroditoides	
	4	Owenia fusiformis	
	4	Sphaerodoridium sp. A	
	4	Sternaspis scutata	
	2	Ampharete arctica	
	2	Antinoella badia	
	2	Apistobanchus tullbergi	
	2	Cistenides hyperborea	
	2	Minuspio cirrifera	
	2	Praxillella praetermissa	

Table 14. con't.

Depth	No/m*	Name	Rank
360 m	690	<i>Maldane sarsi</i>	1
	302	<i>Scoloplos acutus</i>	2
	224	<i>Levinsenia gracilis</i>	3
	208	<i>Minuspio cirrifera</i>	4
	142	<i>Lumbrineris minuta</i>	5
	92	<i>Barantolla</i> sp.	6
	78	<i>Laonice cirrata</i>	7.5
	78	<i>Micronephthys minuta</i>	7.5
	74	<i>Ophelina cylindricaudatus</i>	9
	60	<i>Tharyx ?acutus</i>	10
	58	<i>Chaetozone setosa</i>	
	44	<i>Aricidea</i> (Allis) <u>cf.</u> <i>A. suecica</i>	
	34	<i>Onuphis quadricuspis</i>	
	30	<i>Heteromastus filiformis</i>	
	26	<i>Eteone longis</i>	
	26	<i>Sternaspis scutata</i>	
	12	<i>Spiochaetopterus typicus</i>	
	12	<i>Trochochaeta carica</i>	
	10	<i>Nephtys ciliata</i>	
	10	<i>Pholoe minuta</i>	
	8	<i>Chone</i> <u>nr.</u> <i>C. murmanica</i>	
	6	<i>Antinoella badia</i>	
	6	<i>Prionospio steenstrupi</i>	
	6	<i>Sphaerodoridium</i> sp. A	
	4	<i>Capitella capitata</i>	
	4	<i>Terebellides stroemi</i>	
	2	<i>Aglaophamus malmgreni</i>	
	2	<i>Cossura longocirrata</i>	
	2	<i>Diplocirrus hirsutus</i>	
	2	<i>Melinna elisabethae</i>	
	2	<i>Nereimyra aphroditoides</i>	



Table 14. con't.

Depth	No/m <sup>2</sup>	Name	Rank
700 m	2042	<i>Minusprio cirrifer</i>	1
	456	<i>Maldane sarsi</i>	2
	90	<i>Laonice cirrata</i>	3
	66	<i>Chaetozone setosa</i>	4
	52	<i>Levinsenia gracilis</i>	5
	44	<i>Lumbrineris minuta</i>	6
	40	<i>Barantolla</i> sp.	7
	38	<i>Scoloplos acutus</i>	8
	34	<i>Aricidea</i> (Allis) <u>cf.</u> <i>A. suecica</i>	9
	30	<i>Cossura longocirrata</i>	10
	26	<i>Chone</i> <u>mr.</u> <i>C. murmanica</i>	
	20	<i>Owenia fusiformis</i>	
	18	<i>Onuphis quadricuspis</i>	
	18	<i>Trochochaeta carica</i>	
	16	<i>Capitella capitata</i>	
	16	<i>Micronephthys minuta</i>	
	14	<i>Sphaerodoridium</i> sp. A	
	10	<i>Eteone longis</i>	
	10	<i>Ophelina cylindrica</i> <i>audatus</i>	
	10	<i>Sternaspis scutata</i>	
	6	<i>Lumbrineris fragilis</i>	
	6	<i>Sphaerodoropsis</i> sp. B	
	6	<i>Spiochaetopterus typicus</i>	
	4	<i>Antinoella badia</i>	
	4	<i>Prionospio steenstrupi</i>	
	4	<i>Sigambra tentaculata</i>	
	2	<i>Anaitides groenlandica</i>	
	2	<i>Aricidea</i> (Acmira) <i>quadrilobata</i>	
	2	<i>Heteromastus filiformis</i>	
	2	<i>Sphaerodoropsis</i> sp. A	
	2	<i>Sphaerodorum gracilis</i>	
	2	<i>Tharyx</i> ? <i>acutus</i>	

Table 14. con't.

Depth	No/m <sup>2</sup>	Name	Rank
1800 m	304	Minuspio cirrifera	1
	126	Sigambra tentaculata	2
	106	Lumbrineris minuta	3
	34	Owenia fusiformis	4
	28	Aricidea (Allis) cf. A. suecica	5
	20	Terebellides stroemi	6
	16	Tachytrypane abbranchiata	7
	12	Capitella capitata	8
	4	Heteromastus filiformis	10
	4	Ophelina cylindridatus	10
	4	Scoloplos acutus	10
	2	Aricidea (Acmira) quadrilobata	
	2	Diplocirrus hirsutus	
	2	Diplocirrus longisetosus	
	2	Onuphis quadricuspis	
	2	Sternaspis scutata	

Table 15. Cross-shelf trends macrofauna station environmental information.

Depth (m)	Sediments (%)				Carbon (%)		Temperature (°C)	Salinity ‰
	gravel	sand	silt	clay	organic	CO <sub>3</sub>		
5	0.0	73.2	16.9	9.9	0.09	3.15	2.08	22.08
10	0.0	53.3	38.8	7.9	0.03	11.60	2.15	22.23
15	---	---	---	---	---	---	1.88	31.45
23	0.0	7.2	40.8	52.0	0.00	6.59	-1.02	31.27
47	20.3	32.7	24.8	22.0	0.04	7.60	---	---
100	0.0	50.3	21.9	27.8	0.95	3.09	-0.95	32.58
200	0.0	11.9	44.6	43.5	---	---	-1.41	33.28
360	0.0	6.1	44.8	49.1	0.67	2.47	0.36	34.99
700	0.0	0.8	44.5	54.7	1.03	1.87	0.38	34.96
1800	0.0	0.6	38.3	61.1	1.20	1.41	---	---

Table 16. Expected species values of **polychaetes** at stations on the Pingok Island cross-shelf transect.

<u>Polychaetes</u>	# ind	# Spp	E(S <sub>n</sub> )
PIB-5	565 4	15 2	.13.07 ----
PIB-10	2927 422	23 11	13.04 3.31
PIB-15	393 215	<b>48</b> 12	<b>45.95</b> 6.57
23 m	827 171	43 12	34.77 5.82
47 m	1370 75	60 11	40.71 8.63
100 m	632 170	48 8	39.054 6.67
200 m	1681 61	34 5	22.82 4.14
360 m	1127 26	31 3	24.61 ----
700 m	1546 143	32 4	22.26 3.55
<b>1800 m</b>	335 204	17 5	----- 3.12



Fig. 44. Photograph of the sea floor on the cross-shelf transect at 19 m depth. A compass suspended from the camera appears in the upper right corner of the photo.

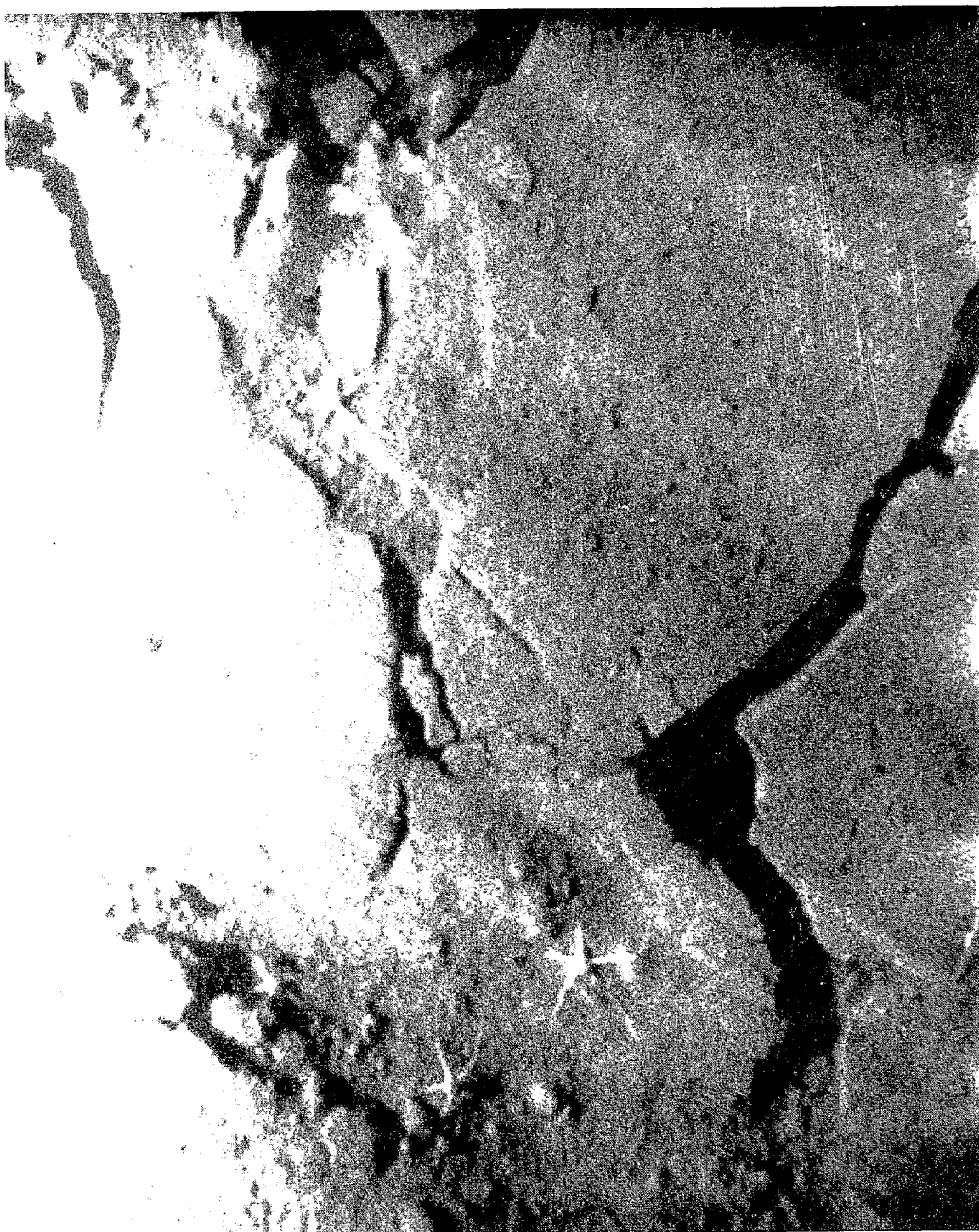


Fig. 45. Photograph of the sea floor on the cross-shelf transect at 24 m depth. The sediments are disrupted due to scour from the overlying ice **pack**. Ophiuroids are visible although the photo resolution is diminished due to suspended sediments in the water column.

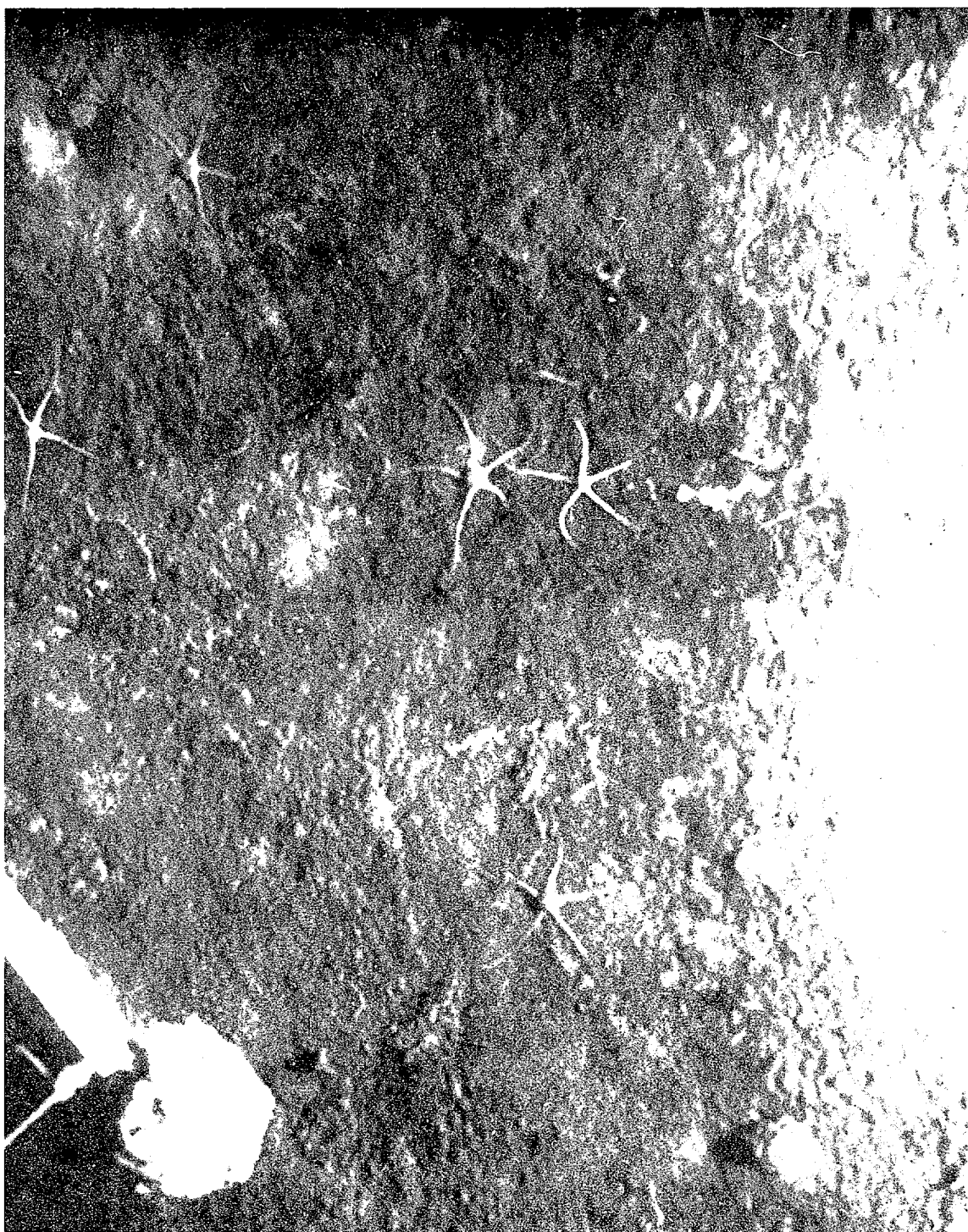


Fig. 46. Photograph of the sea floor on the cross-shelf transect at 25 m depth. Numerous ophiuroids are visible.



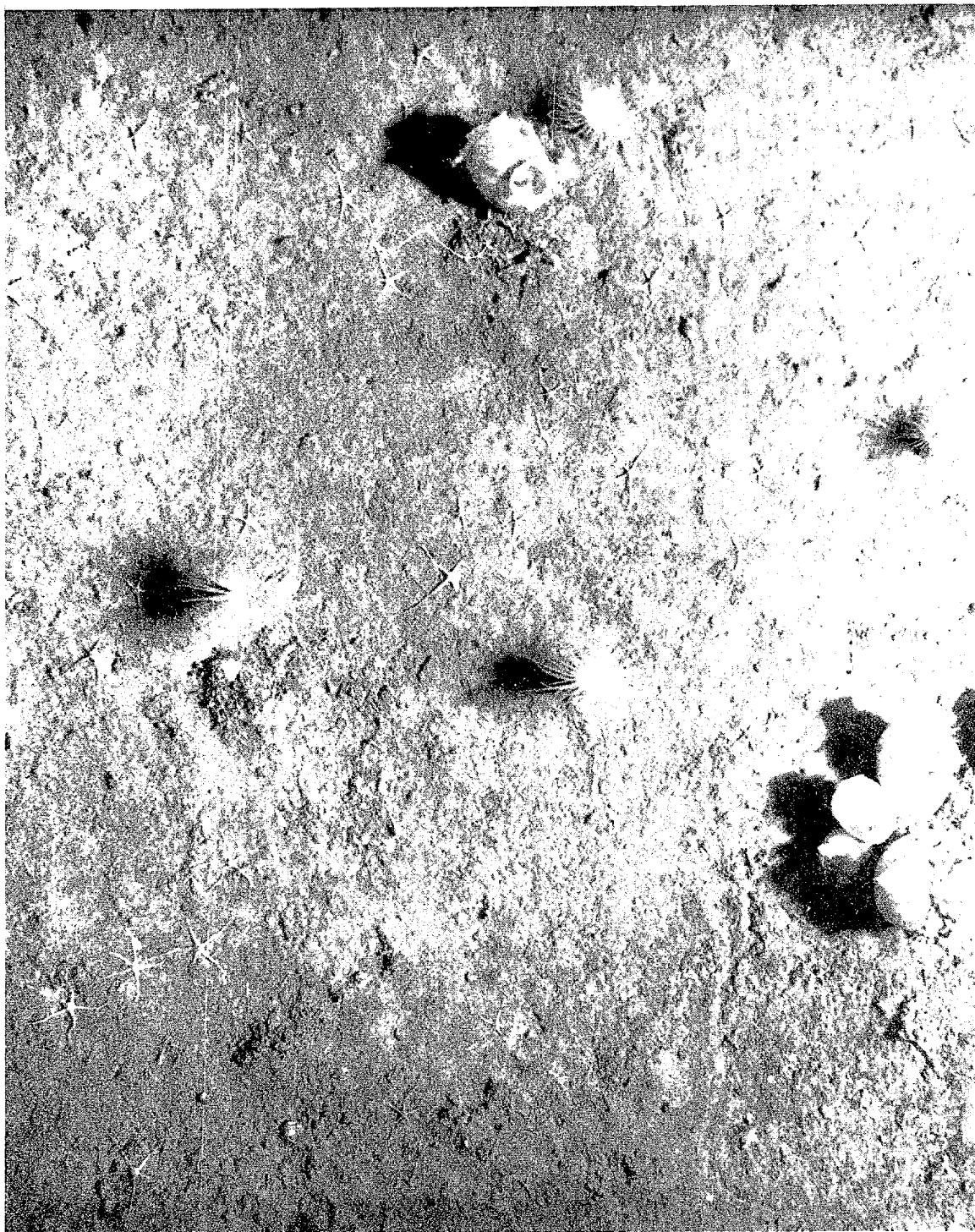


Fig. 47. Photograph of the sea floor on the cross-shelf transect at 44 m depth. Visible organisms include ophiuroids, **tunicates**, and burrowing sea anemones.



Fig. 48. Photograph of the sea floor on the cross-shelf transect at 80 m depth. Sea anemones and an abundant ophiuroid fauna are present. The shadow in the center right of the photo is cast by a compass vane suspended beneath the camera frame.



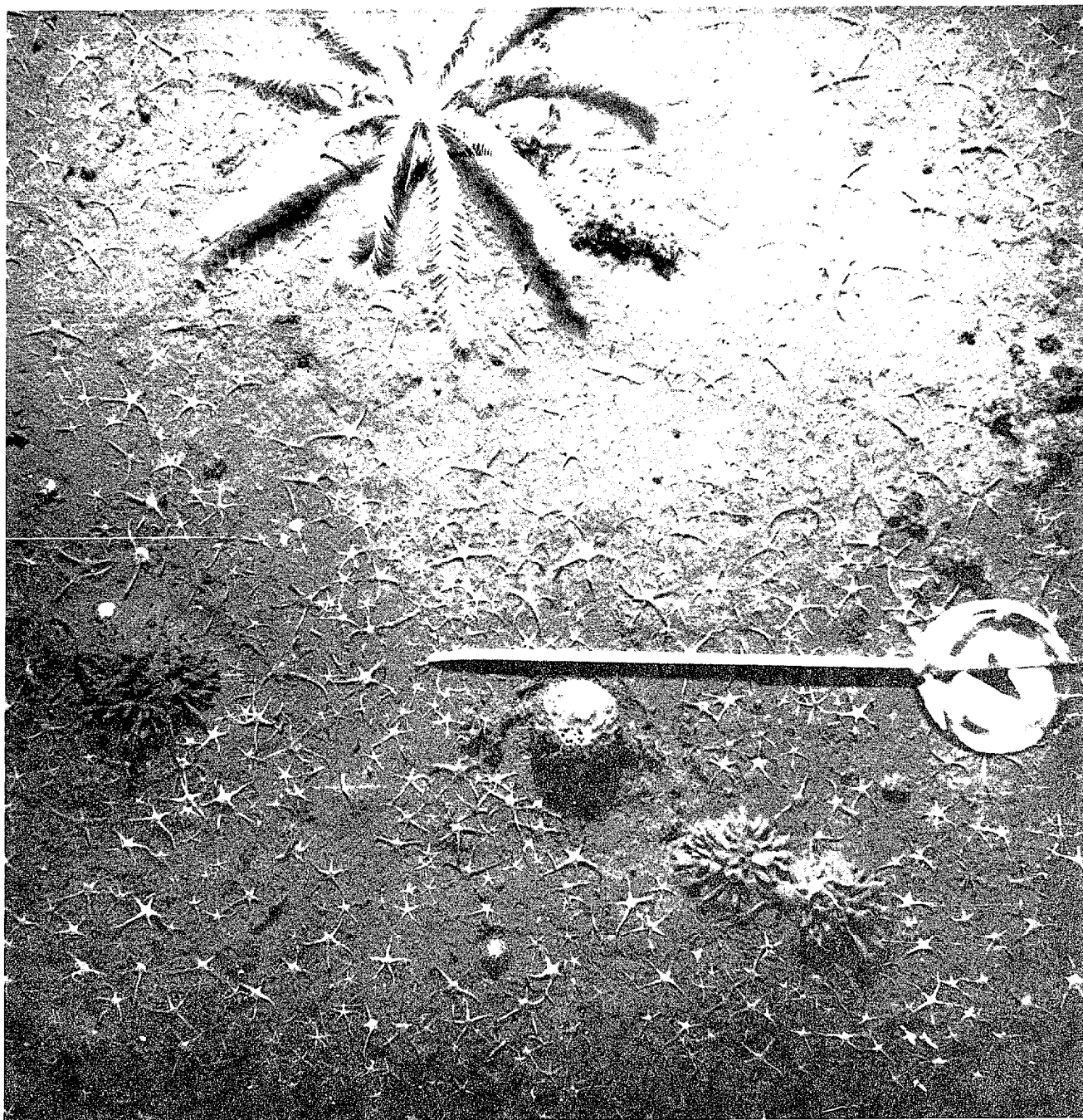


Fig. 49. Photograph of the sea floor on the cross-shelf transect at 145 m depth. Numerous ophiuroids, sponges, and a **comatulid** crinoid are evident.



Fig. 50. Photograph of the sea floor on the cross-shelf transect at 195 m depth. Ophiuroids, anemones, and shrimp are present, and a partially buried asteroid is visible at the top center of the photograph.

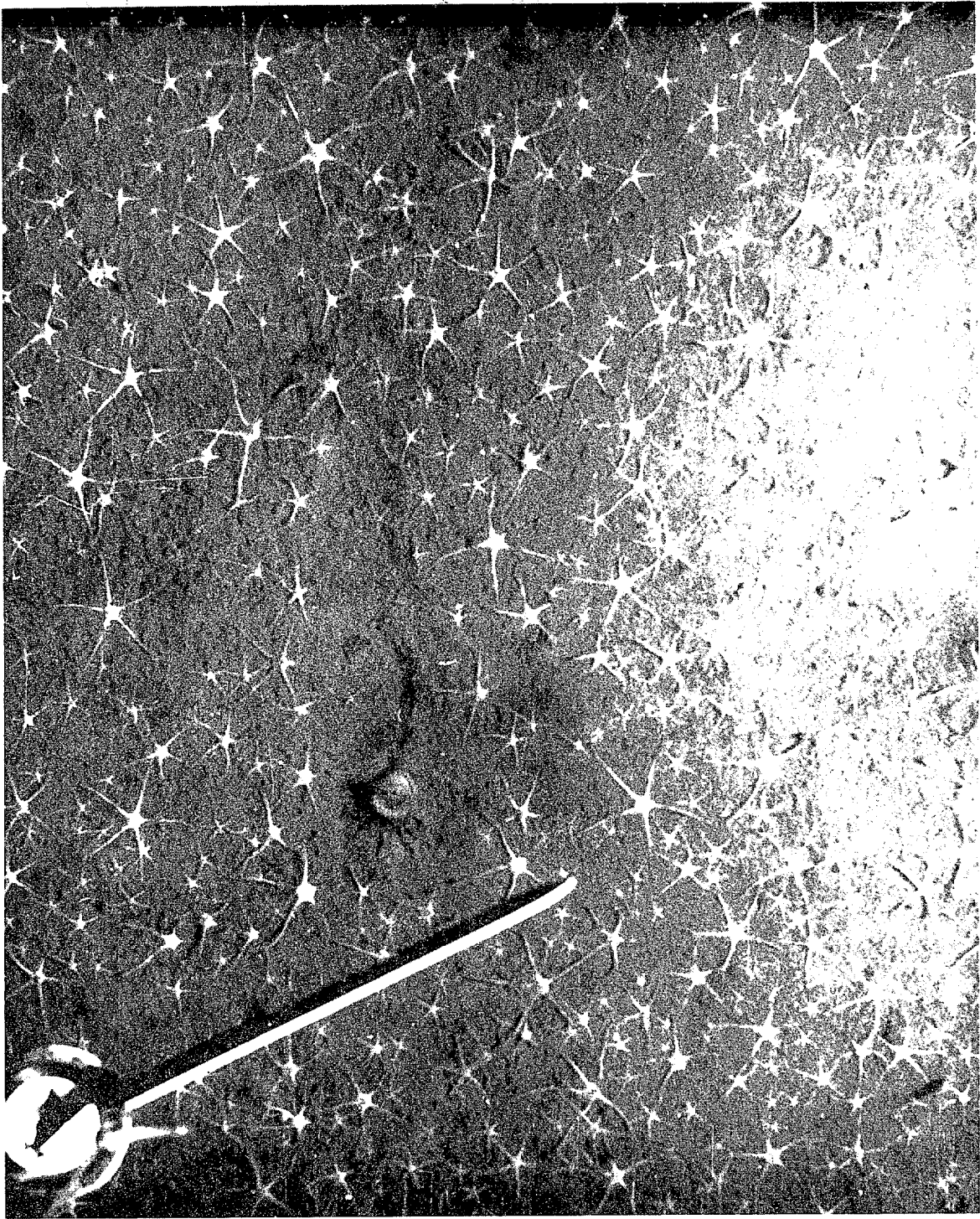


Fig. 51. Photograph of the sea floor on the cross-shelf transect at 350 m depth. An abundant ophiuroid fauna is evident.



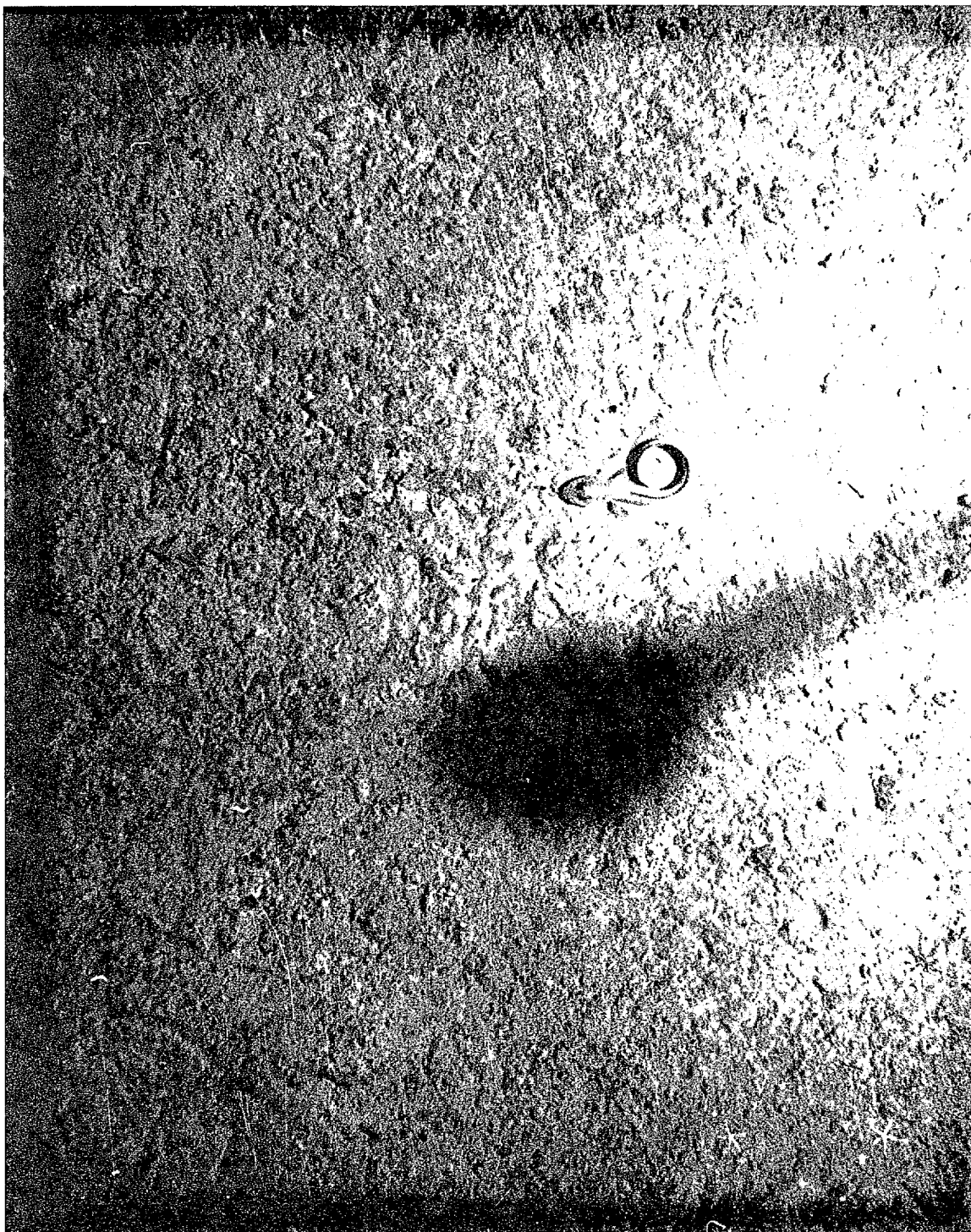


Fig. 52. Photograph of the sea floor on the cross-shelf transect at 750 m depth. Only a few ophiuroids and a zoarcid are visible.

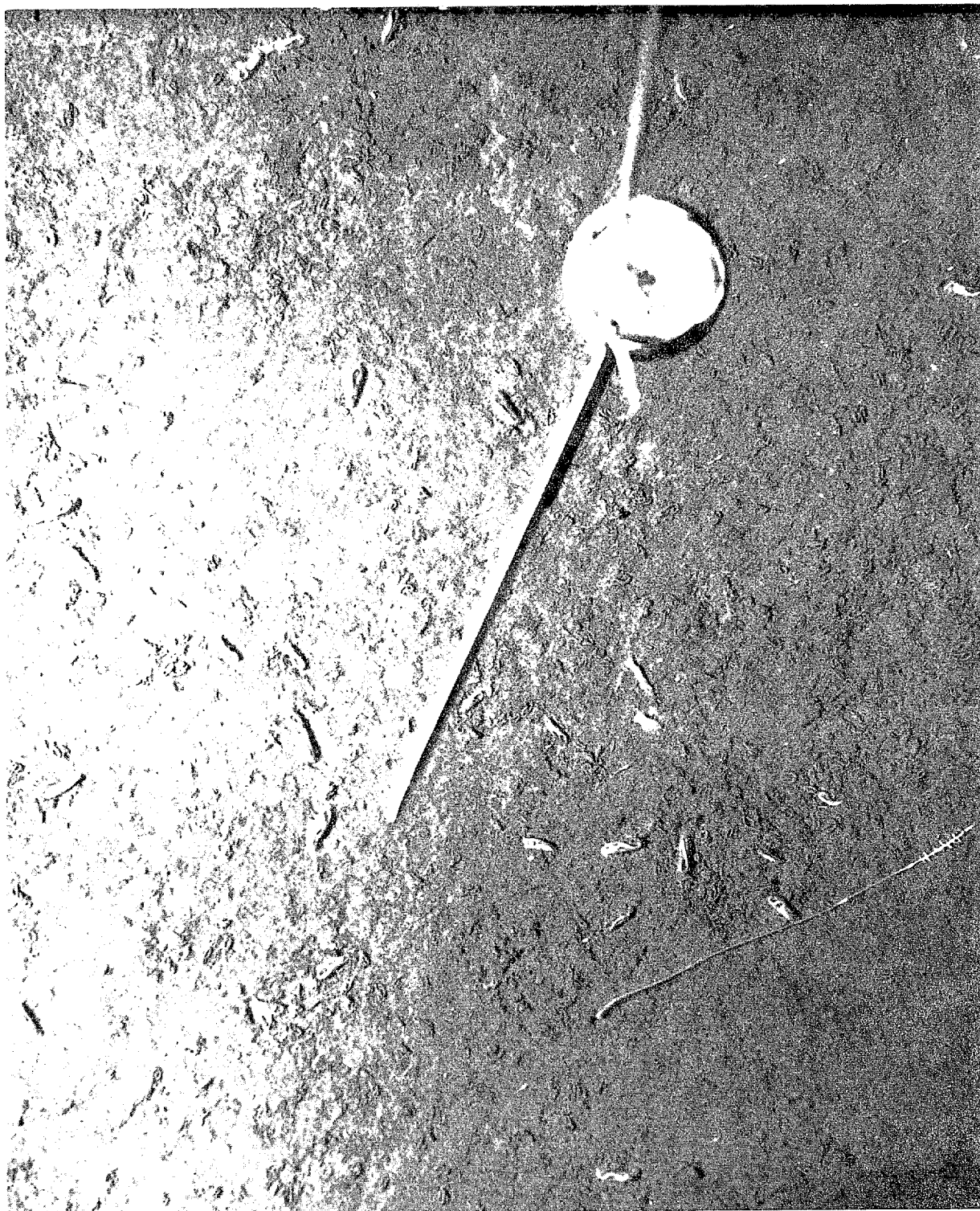


Fig. 53. Photograph of the sea floor on the cross-shelf transect at 1900 m depth. Numerous **holothuroids** dominate the sediment surface, although **cumaceans** and a sea pen are also visible.

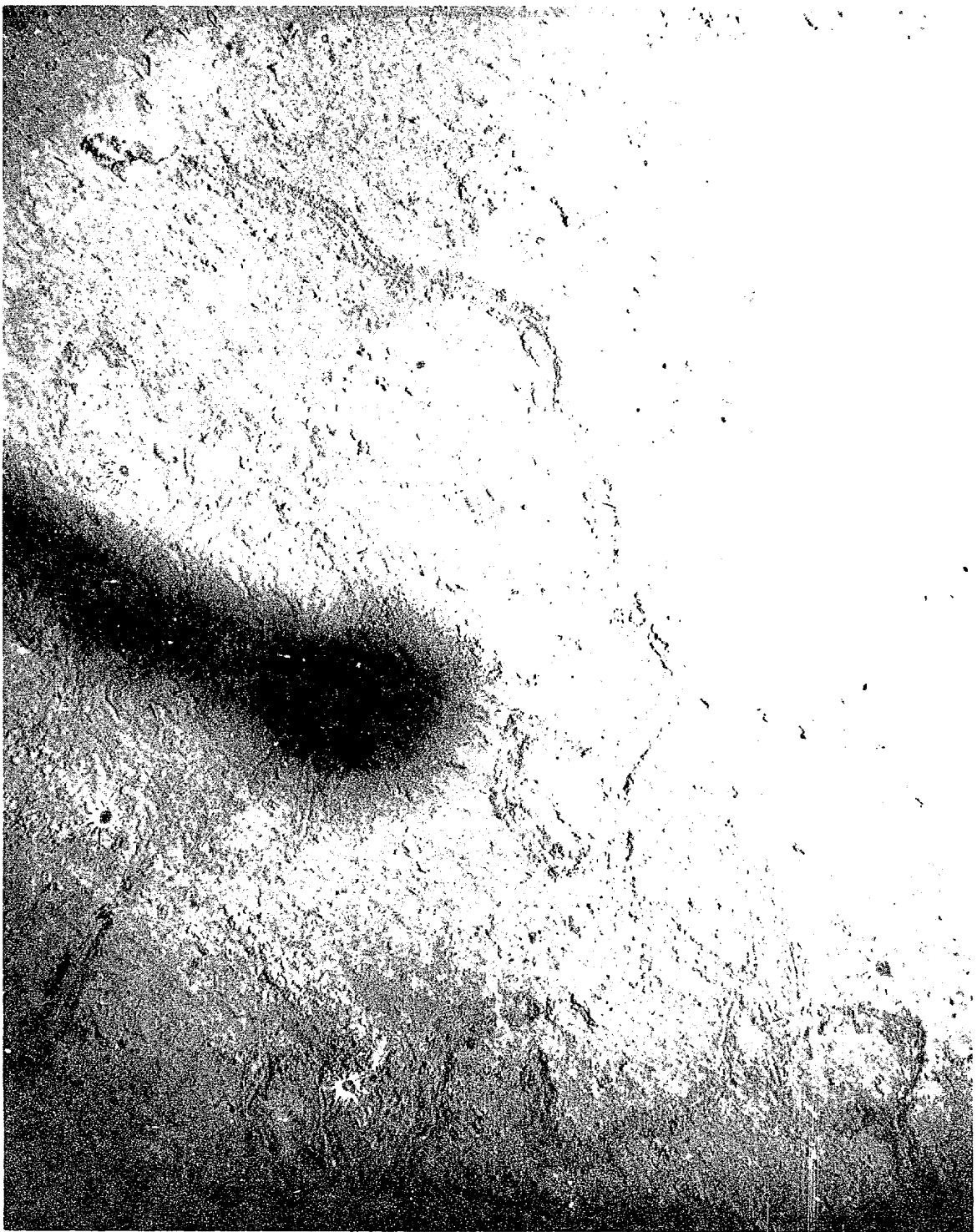


Fig. 54. Photograph of the sea floor on the cross-shelf transect at 2160 m depth. A number of sea anemones are evident in the sediments. The trails visible in the bottom and center of the photo are made by a large isopod which can be seen in the upper left corner.

Appendix II. Narwhal Island Ice Station data collected during project Sea Ice-80.

Table 17. Sampling program used in 1980 sea ice meiofauna study (Kern, 1981).

Ice Meiofauna Samples			
Date	# of quadrats sample d	# of cores per quadrat	total # of cores from uncaged ice
4/14	\$		
4/24	3*	3	9
5/5	3	3	9
5/11	3*	2	6
5/15	3	2	6
5/19	3	2	6
5/26	3	2	6
6/2	3	2	6
6/5	\$		

\$ - Ice scraper samples taken within 40 m of study grid; used only for life-history studies.

\* - Cores taken slightly outside study grid.



Table 18. Animal densities from ice nets (INB) from Narwhal Island ice station (NIO) collected on April 13 through June 9, 1980.

Net	Date	Animal Group						Total
		Amphipod	Cycle.	Harpac.	Calan.	Cnidaria	Polychaeta	
Number								
Total								
INB 1	April 13	252						252
INB 2	"	195						195
INB 3	"	69						69
INB 4	"	11						11
INB 5	"	113	1					114
Total		640	1	--	--	--	--	641
INB 6	April 19	50						50
INB 7	"	70						70
INB 8	"	117			3	2	1	123
INB 9	"	45						45
INB 10	"	121						121
Total		403	--	--	3	2	i	409
INB 11	May 5	37						37
INB 12	"	38						38
INB 13	"	32						32
INB 14	"	21					1	22
INB 15	"	51						51
Total		179	.	--	--	--	T	180
INB 16	May 17	30			1	1		32
INB 17	"	172			13			185
INB 18	"	72						72
INB 19	"	50			1			51
INB 20	"	135						135
Total		459	--	--	15	T	--	475
INB 21	May 31	36			3			39
INB 22	"	105				2		107
INB 23	"	55						55
INB 24	"	136						136
INB 25	"	98						98
Total		430	--	--	3	2	--	435
INB 26	June 9	805		2	7	1		815
INB 27	"	905		4	1			910
INB 28	"	2082		10	1			1093
INB 29	"	1144				1		1145
INB 30	"	464		2				466
INB 31	"	1564		2	1			1567
INB 32	"	1462		15				1477
INB 33	"	630		1				631
INB 34	"	512		6	1			519
INB 35	"	718		46				725
Tot al		10,286	--	48	11	3	--	10,348

Table 19. Numerical abundance and total wet weight of gammarid amphipod species collected from the underice surface at the Narwhal Island ice station.

Sampling date	Species	Abundance			Total wet weight (mg)		
		$\Sigma$	$\sigma_m$	$\bar{x}$	$\Sigma$	$\sigma_m$	$\bar{x}$
13 April 1980	<u>Pseudalibrotus litoralis</u>	500	10.0	92.50	13504.3	2700.9	$\pm 2370.0$
	<u>Weyprechtia pinguis</u>	4	0.8	1.30	146.7	49.2	$\pm 29.3$
	<u>Lagunogammarus setosus</u>	2	0.4	0.55	--	--	--
	<u>Apherusa glacialis</u>	1	0.2	0.45	9.5	1.9	$\pm 3.8$
	<u>Pseudalibrotus sp.</u>	111	22.2	20.35	142.6	28.5	$\pm 22.5$
	(Amphipoda spp.) <sup>1</sup>	20	4.0	4.69	--	--	--
19 April 1980	<u>Pseudalibrotus litoralis</u>	73	14.6	20.34	1715.6	343.1	$\pm 427.9$
	<u>Halirages mixtus</u>	8	1.4	1.34	87.8	17.6	$\pm 15.4$
	<u>Apherusa glacialis</u>	5	1.0	1.22	20.4	4.1	$\pm 4.5$
	<u>Gammaridae sp. A</u>	2	0.4	0.89	--	--	--
	<u>Lagunogammarus setosus</u>	1	0.2	0.45	3.5	0.7	$\pm 1.4$
	(Amphipoda spp.) <sup>1</sup>	262	52.4	50.73	--	--	--
	<u>Pseudalibrotus sp.</u>	60	12.0	4.85	61.5	12.3	$\pm 6.8$
	(Gammaridae) <sup>2</sup>	1	0.2	0.45	--	--	--
5 May 1980	<u>Pseudalibrotus litoralis</u>	43	8.6	7.64	1223.8	244.8	$\pm 220.1$
	<u>Halirages mixtus</u>	2	0.4	0.55	21.8	4.4	$\pm 5.6$
	<u>Lagunogammarus setosus</u>	2	0.4	0.55	97.6	19.5	$\pm 36.8$
	(Calliopidae) <sup>3</sup>	1	0.2	0.45	--	--	--
	<u>Pseudalibrotus sp.</u>	127	25.4	14.03	172.9	34.6	$\pm 15.5$
17 May 1980	<u>Pseudalibrotus litoralis</u>	74	14.8	16.77	2163.2	432.6	$\pm 444.4$
	<u>Halirages mixtus</u>	16	3.2	1.92	246.8	49.4	$\pm 32.6$
	<u>Gammaridae sp. A</u>	2	0.4	0.55	--	--	--
	<u>Weyprechtia pingus</u>	1	0.2	0.45	13.9	2.8	$\pm 5.6$
	(Amphipoda spp.) <sup>1</sup>	239	47.8	45.12	--	--	--
	<u>Pseudalibrotus sp.</u>	117	23.4	10.36	152.6	30.5	$\pm 13.9$
	<u>Weyprechtia pingus</u>	9	1.8	2.05	--	--	--
	<u>Lagunogammarus setosus</u>	3	0.6	0.55	--	--	--

Table 19. (cent. )

Sampling date	Species	Abundance			Total wet weight (mg)		
		$\Sigma$	$\sigma_m$	x	$\Sigma$	$\sigma_m$	$\bar{x}$
31 May 1980	<u>Pseudalibrotus litoralis</u>	103	19.6	$\pm 14.05$	3185.9	637.2	$\pm 403.5$
	<u>Lagunogammarus setosus</u>	9	1.8	$\pm 2.49$	1211.7	242.3	-I-297.4
	<u>Halirgaes mixtus</u>	2	0.4	$\pm 0.55$	16.5	3.3	$\pm 4.1$
	<u>Pseudalibrotus</u> sp.	189	37.8	$\pm 19.02$	314.3	62.9	$\pm 25.2$
	(Amphipoda sp.) <sup>1</sup>	115	23.0	$\pm 10.32$	--	--	--
	<u>Weyprechtia pinguis</u>	2	0.4	$\pm 0.55$	--	--	--
9 June 1980	<u>Pseudalibrotus litoralis</u>	157	15.8	$\pm 18.02$	5753.6	575.4	$\pm 627.0$
	<u>Lagunogammarus setosus</u>	29	2.9	$\pm 5.55$	3533.6	353.4	$\pm 878.9$
	<u>Apherusa glacialis</u>	27	2.7	$\pm 2.75$	231.3	23.1	$\pm 23.8$
	<u>Halirages mixtus</u>	24	2.4	$\pm 2.37$	317.6	31.8	$\pm 31.5$
	<u>Weyprechtia pinguis</u>	4	0.4	$\pm 0.97$	114.0	11.4	$\pm 24.7$
	(Calliopiidae) <sup>3</sup>	1	0.1	$\pm 0.32$	--	--	--
	<u>Pseudalibrotus</u> sp.	6496	349.0	$\pm 334.79$	6623.8	662.4	$\pm 576.2$
	(Amphipoda spp.) <sup>1</sup>	3491	649.6	$\pm 411.06$	--	--	--
	<u>Lagunogammarus setosus</u>	18	1.8	$\pm 1.99$	--	--	--
	<u>Weyprechtia pinguis</u>	3	0.3	$\pm 0.95$	--	--	--
	(Gammaridae) <sup>2</sup>	1	0.1	$\pm 0.32$	--	--	--

<sup>1</sup> includes Halirages sp., Weyprechtia sp., and/or Apherusa sp.; possibly others

<sup>2</sup> includes Halirages sp., Weyprechtia sp., and/or Apherusa sp.; possibly others

<sup>3</sup> ?Lagunogammarus sp.

Table 20. Animal densities from sediment nets (SNB) collected at Narwhal Island ice station (NIO) on April 17, 1980 (OCS-11).

Phylum	Class	Order	Net Number					TOTAL
			SNB1	SNB2	SNB3	SNB4	SNB5	
Protozoa	Rhizopodea	Foraminifera		4	5		2	11
Annelida	Polychaeta				1			1
	Hirudinea				1	1		2
Arthropoda	Crustacea	Amphipoda	252	6	17	5	20	300
		Harpacticoida	1	1				2
		Ostracoda	2	2	8	1	1	14
		Cumacea	2		5			7
		Mysidacea	26	2	23	24	2	77
		TOTAL	283	15	60	31	25	414

Table 21. Animal densities from sediment nets (SNB) collected at Narwhal Island ice station (NIO) on May 2, 1980 (OCS-11).

Phylum	Class	Order	Net Number					TOTAL
			SNB6	SNB7	SNB8	SNB9	SNB10	
Arthropoda	Crustacea	Amphipoda	16	12	13	11	23	75
		Ostracoda		2		4	1	7
		Cumacea	1	3	1	2	1	8
		Mysidacea	11	4	6	10	16	47
		TOTAL	28	21	20	27	41	137

Table 22. Animal densities from sediment nets (SNB) collected at Narwhal Island ice station (NIO) on May 29, 1980 (OCS-11).

Phylum	Class	Order	Net Number					TOTAL
			SNB11	SNB12	SNB13	SNB14	SNB15	
Protozoa	Rhizopodea	Foraminifera	9	8	6	11	6	40
Annelida	Polychaeta			1				1
Arthropoda	Crustacea	Amphipoda	17	34	17	44	32	144
		Ostracoda	1	6	6	10	12	35
		Cumacea	4	12	6	9	3	34
		Mysidacea	5	2	5	5	7	24
Mollusca	Pelecypoda					1	3	4
	Gastropoda						2	2
		TOTAL	36	63	40	80	65	284

Table 23. Animal densities from sediment nets (SNB) collected at Narwhal Island ice station (N10) on June 7, 1980 (OCS-II) .

Phylum	Class	Order	SNB16	SNB17	SNB18	SNB19	SNB20	SNB21	SNB22	SNB23	SNB24	SNB25	TOTAL
Protozoa	Rhizopodea	Foraminifera	5	6	8	14	21	13	27	34	2a	12	168
Nemertinea									1				1
Annelida	Polychaeta				1	3	6						10
Arthropoda	Crustacea	Amphipoda	49	69	72	71	167	70	74	48	102	135	857
		Harpacticoida						1		1			2
		Ostracoda	2	7	11	9	30	9	14	4	7	9	102
		Cumacea	32	35	36	60	91	42	128	89	107	76	696
		Mysidacea	14	17	11	11	10	7	8	5	14	14	111
Mollusca	Pelecypoda				1		2	1		2			6
	Gastropoda		1			1					1		3
		TOTAL	103	134	140	169	327	143	252	183	259	246	1956

Table 24. Environmental data measured at the Narwhal Island ice station during spring, 1980.

<u>Date/Time</u>	<u>Depth(m)</u>	<u>Conductivity</u>	<u>Salinity (‰)</u>	<u>Temperature (°C)</u>
17 Apr 80	0	27.41	35.82	-1.82
	1	27.24	35.93	-2.00
	2	27.08	35.64	-2.00
	<b>3</b>	27.08	35.09	-2.00
	4	27.07	35.28	<-2.00
	5	<b>27.14</b>	35.57	<-2.00
	6	<b>27.13</b>	35.45	<-2.00
	7	27.15	35.82	<-2.00
	8	27.24	36.02	<-2.00
19 Apr 80	1315	0	27.37	-1.40
		<b>1</b>	27.14	<-1.50
		2	27.10	<-2.00
		3	<b>27.10</b>	<-2.00
		4	<b>27.17</b>	<-2.00
		5	27.23	<-2.00
		6	27.34	<-2.00
	1625	0	27.16	-1.70
		6	27.33	<-2.00
24 Apr 80	1201	0	26.80	-1.70
		1	26.74	<-2.00
		2	26.75	-2.00
		3	26.78	<-2.00
		4	26.76	<-2.00
		5	26.75	<-2.00
		6	27.15	<-2.00
	1500	0	26.78	<-2.00
		6	27.82	<-2.00
28 Apr 80	1909	0	26.88	-2.00
		1	26.89	<-2.00
		2	26.86	<-2.00
		<b>3</b>	26.86	<-2.00
		4	26.91	<-2.00
		5	27.00	<-2.00
		6	27.24	<-2.00
30 Apr 80	0845	0	26.74	<-2.00
		1	26.80	<-2.00
		2	26.82	<-2.00
		3	26.82	<-2.00
		4	26.98	<-2.00
		5	27.06	<-2.00
		6	27.39	<-2.00
	1035	0	26.77	<-2.00
		6	27.30	<-2.00

Table 24. (cent. )

<u>Date/Time</u>		<u>Depth(m)</u>	<u>Conductivity</u>	<u>Salinity (‰)</u>	<u>Temperature (°C)</u>
30 Apr	1235	0	26.84	34.86	<-2.1313
		1	26.82	34.37	-1.78
		2	26.85	34.70	-1.73
		3	26.85	35.01	<-2.00
		4	26.86	35.26	<-2.00
		5	26.90	35.42	<-2.00
		6	27.35	36.23	<-2.00
	1436	0	26.76	35.05	<-2.0
		6	<b>27.14</b>	35.69	<-2.0
	1638	0	26.79	33.74	-1.69
		1	26.75	34.70	-2.00
		<b>3</b>	26.78	34.88	<-2.00
		<b>4</b>	26.98	35.33	<-2.00
		5	<b>27.19</b>	35.51	<-2.00
		6	27.30	35.90	<-2.00
	1834	0	26.76	35.14	<-2. (30
		6	27.29	35.91	<-2.00
	2032	0	26.92	35.05	<-2.00
		<b>1</b>	26.84	35.23	<-2.00
		2	26.84	35.20	<-2.00
		3	26.84	35.27	<-2.00
		4	26.94	35.51	<-2.00
		5	27.33	35.98	<-2.00
		6	27.40	35.98	<-2.00
	2230	0	26.86	35.21	<-2.00
		6	27.49	36.52	<-2.00
1 May 80	0034	0	26.81	35.08	<-2.00
		1	26.85	35.16	<-2.00
		2	26.85	35.34	<-2.00
		3	26.91	35.41	<-2.00
		4	27.12	35.80	<-2.00
		5	27.15	35.92	<-2.1)13
		6	27.38	36.21	<-2.00
	0240	0	26.83	35.08	<-2.00
		6	27.42	36.06	<-2.00
	0447	0	26.83	34.45	-1.65
		<b>1</b>	26.82	34.84	<-2.00
		2	26.82	34.95	<-2.00
		3	26.83	35.18	<-2.00
		4	26.89	35.38	<-2.00
		5	27.29	36.03	<-2.00
		6	27.37	36.14	<-2.00
	0650	0	26.77	34.93	<-2.00
		6	27.16	35.58	<-2.00

Table 24. (cent. )

Date/Time		Depth (m)	Conductivity	Salinity(‰)	Temperature (°C)
5 May 80	0930	0	27.08	33.40	-1.30
		1	26.86	34.92	<-2.00
		2	26.87	35.05	<-2.00
		3	26.87	35.23	<-2.00
		4	27.03	35.41	<-2.00
		5	27.13	35.50	<-2.00
		6	27.55	36.39	<-2.00
	1533	0	26.91	35.23	<-2.00
		6	27.2.5	36.00	<-2.00
	0920	0	27.10	33.68	-0.78
		1	26.88	33.93	-0.91
		2	26.86	34.08	-0.97
<b>3</b>		26.93	34.99	<-2.00	
<b>4</b>		27.28	35.62	<-2.00	
5		27.45	36.31	<-2.00	
6		27.59	36.50	<-2.3(3	
7 May 80	0935	0	27.03	34.80	-2.00
		1	26.91	35.28	<-2.00
		2	26.93	35.00	<-2.00
		3	26.93	35.21	<-2.00
		4	27.31	35.95	<-2.00
		5	27.49	36.32	<-2.00
		6	27.54	36.40	<-2.00
	1135	0	26.94	35.50	<-2.00
		6	27.55	36.79	<-2.00
	1330	0	26.71	35.56	<-2.00
		1	26.96	35.87	<-2.00
		2	27.00	35.84	<-2.00
3		7.00	35.93	<-2.00	
4		27.25	36.27	<-2.00	
5		27.55	36.62	<-2.00	
6		27.69	36.81	<-2.00	
1535	0	26.91	35.77	<-2.00	
	6	27.55	36.80	<-2.00	
1758	0	26.81	35.87	<-2.00	
	<b>1</b>	26.93	35.89	<-2.00	
	2	26.93	35.89	<-2.00	
	3	26.92	35.75	<-2.00	
	4	26.96	35.74	<-2.00	
	5	27.18	36.21	<-2.00	
	6	<b>27.52</b>	36.67	<-2.00	
1934	0	26.93	35.74	<-2.00	
	6	26.99	36.19	<-2.00	



Table 24. (cont.)

<u>Date/Time</u>		<u>Depth(m)</u>	<u>Conductivity</u>	<u>Salinity ‰</u>	<u>Temperature (°C)</u>
7 May 80	2135	0	26.62	36.15	<-2.00
		1	26.92	36.52	<-2.00
		2	26.93	36.39	<-2.00
		3	26.95	36.34	<-2.00
		4	26.99	36.40	<-2.00
		5	27.42	36.98	<-2.00
		6	27.55	36.80	<-2.00
	2330	0	26.88	36.33	<-2.00
		6	27.45	37.69	<-2.00
	0145	0	26.46	38.53	<<-2.00
		1	26.84	39.17	<<-2.00
		2	26.80	39.17	<<-2.00
		3	26.80	38.63	<<-2.00
		4	27.02	38.90	<<-2.00
		5	27.44	39.58	<<-2.00
		6	27.53	39.83	<<-2.00
	0330	0	26.57	39.31	<<-2.00
		6	26.92	40.00	<<-2.00
11 May 80	1605	0	26.90	34.70	-1.90
		1	26.79	34.92	<-2.00
		2	26.80	35.10	<-2.00
		3	26.80	35.20	<-2.00
		4	26.90	34.60	-1.99
		5	27.19	36.00	<-2.00
		6	27.39	36.30	<-2.00
15 May 80	1430	0	26.94	35.36	<-2.00
		1	26.96	35.30	<-2.00
		2	26.98	35.60	<-2.00
		3	26.90	35.42	<-2.00
		4	26.96	35.54	<-2.00
		5	27.02	35.78	<-2.00
		6	27.10	35.78	<-2.00
17 May 80	1149	0	26.88	35.30	<-2.00
		1	26.88	35.88	<-2.00
		2	26.98	35.70	<-2.00
		3	26.96	35.70	<-2.00
		4	27.06	35.72	<-2.00
		5	27.08	35.82	<-2.00
		6	27.13	36.00	<-2.00
19 May 80	0947	0	26.62	36.22	<-2.00
		1	26.72	35.44	<-2.00
		2	26.74	35.46	<-2.00
		3	26.76	35.60	<-2.00
		4	26.76	35.60	<-2.00
		5	27.06	36.20	<-2.00
		6	27.15	36.14	<-2.00

Table 24. (cent. )

Date/Time		Depth (m)	Conductivity	Salinity (‰)	Temperature (°C)
19 May 80	1145	0	26.76	35.20	<-2.00
		6	27.15	36.10	<-2.00
	1350	0	26.85	34.22	-0.80
		1	26.73	34.92	-2.00
		3	26.71	34.80	<-2.00
		4	26.74	35.12	<-2.00
		5	26.81	35.40	<-2.00
		6	26.94	35.56	<-2.130
	1742	0	26.80	32.60	0.10
		6	26.92	34.20	-1.30
	1929	0	27.08	33.14	-0.76
		1	26.84	33.30	-1.50
		2	26.84	35.00	-1.77
		3	26.88	34.92	<-2.00
		4	26.84	35.10	<-2.00
		5	26.92	35.48	<-2.00
		6	27.08	35.48	<-2.00
	2135	0	26.90	34.40	-1.30
		6	26.17	35.85	<-2.00
	2340	0	26.90	34.24	-1.70
		1	26.90	35.26	<-2.00
		2	26.90	35.20	<-2.00
		3	26.90	35.60	<-2.00
		4	26.90	35.18	<-2.00
		5	27.10	35.80	<-2.00
		6	27.26	36.12	<-2.00
20 May 80	0730	0	26.78	33.82	-1.08
		1	26.74	34.06	-1.97
		2	26.76	34.58	-1.74
		3	26.74	34.50	-2.00
		4	26.74	34.90	<-2.00
		5	26.94	34.73	<-2.00
		6	27.42	36.20	<-2.00
	1240	0	26.18	33.59	-2.00
		1	26.28	34.27	<-2.00
		2	26.34	34.27	<-2.00
		3	26.34	34.48	<-2.00
		4	26.34	34.16	<-2.00
22 May 80	0930	5	26.50	34.30	<-2.00
		6	26.84	35.42	<-2.00
	1240	0	26.31	34.20	<-2.00
		1	26.32	34.50	<-2.00
		2	26.31	34.43	<-2.00
		3	26.32	34.43	<-2.00
		4	26.42	34.62	<-2.00
	0930	5	26.42	34.54	<-2.00
		6	26.54	34.96	<-2.00

Table 24. (cont.)

<u>Date/Time</u>	<u>Depth (m)</u>	<u>Conductivity</u>	<u>Salinity (e/.. )</u>	<u>Temperature (°C)</u>
29 May 80 0900	0	26.55	34.94	<-2.00
	1	26.55	34.98	<-2.00
	2	26.54	34.93	<-2.00
	3	26.56	34.94	<-2.00
	4	26.61	34.96	<-2.00
	5	26.65	35.06	<-2.00
	6	26.70	35.08	<-2.00
31 May 80 0945	0	26.50	<b>35.04</b>	<-2.00
	<b>1</b>	26.58	34.96	<-2.00
	2	26.58	35.12	<-2.00
	3	26.61	35.22	<-2.00
	4	26.68	35.22	<-2.00
	5	26.75	35.22	<-2.00
	6	26.85	35.22	<-2.00
2 June 80 0900	0	26.59	34.84	<-2.00
	1	26.62	34.84	<-2.00
	2	26.65	34.90	<-2.00
	<b>3</b>	26.69	34.98	<-2.00
	<b>4</b>	26.66	35.05	<-2.00
	5	26.70	<b>35.11</b>	<-2.00
	6	26.75	<b>35.11</b>	<-2.00
	1100	0	26.65	-1.75
		6	26.96	<-2.00
	1300	0	26.64	<b>+0.57</b>
		<b>1</b>	26.76	<-2.00
		2	26.76	<-2.00
		3	26.76	<-2.00
		4	26.78	<-2.00
		5	26.85	<-2.00
		6	26.82	<-2.00
	1500	0	26.76	<b>+0.59</b>
		6	26.69	<-2.00
	1700	0	27.04	<b>+0.09</b>
		1	26.81	<-2.00
		2	26.83	-1.85
		3	26.81	<-2.00
		4	26.81	<-2.00
		5	26.82	<-2.00
		6	26.85	<-2.00
	1900	0	<b>27.01</b>	-0.51
		6	26.90	<b>-1.65</b>
	2100	0	27.01	<b>-1.03</b>
		1	26.83	<-2.00
		2	26.83	<-2.00
		3	26.83	<-2.00
		4	26.82	<-2.00
		5	26.85	<-2.00
		6	26.85	<-2.00

Table 24. (cent. )

<u>Date/Time</u>	<u>Depth(m)</u>	<u>Conductivity</u>	<u>Salinity(‰)</u>	<u>Temperature (°C)</u>
2 June 80 2300	0	26.97	31.26	+0.64
	6	26.94	33.82	-0.70
3 June 80 0100	0	27.00	<b>31.39</b>	<b>+1.14</b>
	1	26.72	32.94	-1.32
	2	26.70	33.74	-1.45
	3	26.74	34.58	-2.00
	4	26.75	34.72	<-2.00
	5	26.79	35.06	<-2.00
	6	26.77	35.04	<-2.00
	0300	0	27.08	+0.82
		6	26.96	<-2.00
	0500	0	26.92	<b>+0.23</b>
		<b>1</b>	26.81	<b>-0.32</b>
		2	26.97	-0.42
		3	26.94	-1.90
		4	26.90	<-2.00
		5	26.93	<-2.00
		6	26.92	<-2.00
	0700	0	26.96	+1.22
		6	27.06	+0.06
5 June 80 0840	0	26.06	33.68	<-2.00
	1	26.75	34.47	-1.90
	2	26.84	35.03	<-2.00
	3	26.86	35.26	<-2.00
	4	26.93	35.26	<-2.00
	5	26.98	35.39	<-2.00
	6	27.01	35.54	<-2.00
7 June 80 0840	0	25.63	32.30	-1.46
	<b>1</b>	26.62	34.51	<-2.00
	2	26.75	34.94	<-2.00
	3	26.77	34.89	<-2.00
	4	26.89	35.23	<-2.00
	5	27.05	35.46	<-2.00
	6	27.10	35.60	<-2.00
9 June 80 0840	0	2.73	2.81	-0.44
	1	26.22	34.06	<-2.00
	2	26.30	33.86	-1.84
	3	26.54	34.71	<-2.00
	4	26.74	35.10	<-2.00
	5	26.87	35.11	<-2.00
	6	26.89	35.28	<-2.00
11 June 80 0833	0	1.56	1.56	-0.31
	<b>1</b>	19.58	23.48	-1.17
	2	26.06	33.82	<-2.00
	3	26.65	34.84	<-2.00
	4	26.76	35.21	<-2.00
	5	26.80	35.03	<-2.00
	6	26.90	35.38	<-2.00

Table 25. Mean abundance per 100 cm<sup>2</sup> for major taxa collected on each sampling date.  $\bar{X}$ : Mean, SD: Standard deviation. The results of one-way ANOVA's are given at right.

Group	$\bar{X}$	4/24 SD	$\bar{X}$	5/5 SD	$\bar{X}$	5/11 SD	$\bar{X}$	5/15 SD
Nematoda	3.59	1.95	9.23	10.51	34.84	33.92	6.36	17.74
Copepoda	50.94	28.13	27.21	13.62	24.63	10.06	57.74	27.59
<b>Turbellaria</b>	2.96	2.53	2.06	2.15	4.82	3.45	6.16	4.42
<b>Polychaeta</b>	51.07	65.30	14.63	19.51	1.35	0.87	9.62	13.12
<b>Amphipoda</b>	2.82	2.09	2.18	2.34	<b>2.31</b>	1.63,	6.54	4.04

Group	$\bar{X}$	5/19 SD	$\bar{X}$	5/26 SD	$\bar{X}$	6/2 SD	Significant Change over time? (P)
Nematoda	<b>175.34</b>	129.66	186.71	145.44	250.22	<b>76.63</b>	yes (<.002)
Copepoda	109.71	56.63	125.11	91.39	69.87	36.51	Yes (<.002)
<b>Turbellaria</b>	52.93	14.56	26.56	9.49	151.67	22.65	<b>Yes (&lt;.002)</b>
<b>Polychaeta</b>	7.89	6.42	18.10	21.86	8.08	5.89	<b>Yes (&lt;.002)</b>
<b>Amphipoda</b>	9.24	7.04	11.93	7.47	2.51	1.99	Yes (<.002)

Table 26. Mean abundance per 100 cm<sup>2</sup> for the five dominant **copepod** species on each sampling date.

$\bar{X}$ : Mean, SD: Standard deviation. The results of one-way ANOVA's are given last.

Group	4/24		5/5		5/11		5/15	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
<u>Cyclopina</u> <u>gracilis</u>	22.97	13.26	15.27	9.43	10.20	5.99	29.65	18.00
<u>Harpacticus</u> sp.	10.39	7.96	6.55	4.65	5.58	3.13	11.74	6.83
<u>Halectinosoma</u> sp.	15.52	11.41	4.11	2.45	8.08	2.92	9.82	7.37
<u>Oncaea</u> sp.	0.51	0.84	0.25	0.51	0.38	0.60	2.51	2.36
<u>Dactylopodia</u> <u>signata</u>	0.77	1.15	0.13	0.38	0.0		0.0	

Group	5/19		5/26		6/2		Significant change over time? (P)	
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD		
<u>Cyclopina</u> <u>gracilis</u>	60.78	34.24	76.99	40.73	34.65	27.27	Yes	(<.002)
<u>Harpacticus</u> sp.	31.56	15.16	17.90	10.65	20.59	13.45	Yes	(<.002)
<u>Halectinosoma</u> sp.	14.05	12.38	27.52	34.51	8.08	5.01	No	
<u>Oncaea</u> sp.	?.35	0.87	0.38	0.95	1.73	2.71	Yes	(<.05)
<u>Dactylopodia</u> <u>signata</u>	0.77	1.19	0.35	0.95	0.0		No	

**Table '27.** Summary of life-history data for Harpacticus **sp.** and Cyclopina gracilis.

**Cyclopina gracilis**

Date	% Females of Adults	% Females of all Sexable	% Adults	% Gravid Females of Adult Females
4/14	94.4	96.0	18.0	0.0
<b>4/24</b>	79.2	68.1	4.9	11.1
5/5	58.2	67.4	56.3	0.0
5/11	32.4	39.5	64.2	9.1
5/15	34.0	41.5	65.4	5.9
5/19	36.1	46.8	46.8	1.9
<b>5/26</b>	43.8	48.1	47.3	4.9
6/2	45.0	47.4	55.6	0.0
6/5	55.0	57.1	60.0	0.0

**Harpacticus** sp.

Date	% Females of Adults	% Females of all Sexable	% Adults	% Gravid Females of Adult Females
4/14			0.0	
4/24		25.0	0.0	
5/5		40.5	0.0	
5/11	11.1	45.0	31.0	0.0
<b>5/15</b>	16.7	34.4	70.0	0.0
<b>5/19</b>	22.8	39.1	62.6	0.0
5/26	42.7	53.8	80.6	6.8
6/2	33.9	56.0	55.1	12.8
6/5	35.3	56.5	51.0	0.0

Table 28. Amphipod species associated with the ice undersurface, water column, and sediments at the Narwhal Island ice station, spring 1980.

Gammarid Amphipod species -

		no. / m <sup>2</sup>
Underice:	<i>Pseudalibrotus litoralis</i>	9,1
	<i>Halirages mixtus</i>	0.5
	<i>Lagunogammarus setosus</i>	0,4
	<i>Apherusa glacialis</i>	0.3
	<i>Weyprechtia pinguis</i>	0,1
Mid-water:	<i>Pseudalibrotus litoralis</i>	
	<i>Halirages mixtus</i>	
	<i>Oedicerus borealis</i>	
	<i>Apherusa glacialis</i>	
	<i>Lagunogammarus setosa</i>	
	? <i>Anonyx nugax</i>	
	<i>Weyprechtia pinguis</i>	
	<i>Monoculodes borealis</i>	
	<i>Acanthostepheia incarinata</i>	
Benthos:	<i>Monoculodes borealis</i>	1,4
	<i>Pseudalibrotus litoralis</i>	0,8
	<i>Onisimus affinis</i>	0.6
	<i>Onisimus plautus</i>	0.3
	<i>Acanthostepheia malmgreni</i>	0.1
	<i>Onisimus cf. derjugini</i>	0.1
	<i>Oedicerus borealis</i>	< 0.1
	<i>Monoculopsis borealis</i>	< 0.1
	<i>Apherusa glacialis</i>	< 0.1
	? <i>Anonyx nugax</i>	< 0.1
	<i>Acanthostepheia incarinata</i>	< 0.1
	<i>Halirages mixtus</i>	< 0.1
	<i>Lagunogammarus setosus</i>	< 0.1



Appendix 111. Narwhal Island Particle Flux data collected during project Sea Ice-80.

Table 29. Sea Ice-80 Particle Data.

Sample Date	Collection Number	Material
24 April 80	Filter 11	51 - fecal pellet 'A'
		3 - fecal pellet 'small A'
		7 - fecal pellet 'B'
		8 - unconsolidated fecal pellets
	Filter 12	104 - fecal pellet 'A'
		9 - fecal pellet. 'small A'
		10 - fecal pellet 'B'
		10 - unconsolidated material
		25 - crustacean exoskeletons
		1 - <b>gammarid</b> amphipod
	Filter 14	1 - <b>calanoid</b> copepod
		1 - ? egg"
		41 - fecal pellet 'A'
		10 - fecal pellet 'small A'
		8 - fecal pellet 'B'
		9 - unconsolidated fecal pellets
3 May 80	Filter 18	10 - crustacean exoskeletons
		2 - <b>gammarid</b> amphipods
		3 - harpacticoid copepods
		40 - fecal pellet 'A'
		20 - fecal pellet 'small A'
	Filter 19	2 - fecal pellet 'B'
		21 - unconsolidated fecal pellets
		13 - crustacean exoskeletons
		17 - fecal pellet 'A'
	Filter 20	10 - fecal pellet 'small A'
		11 - fecal pellet 'B'
		11 - unconsolidated fecal pellets
		1 - crustacean exoskeletons
		34 - fecal pellet 'A'
		16 - fecal pellet 'small A'
		4 - fecal pellet 'B'
		9 - unconsolidated fecal pellets
		88 - crustacean exoskeletons
		3 - harpacticoid copepods
		1 - <b>cumacean</b>

Table 29. con't.

Sample Date	Collection Number	Material
11 May	Filter 26	56 - fecal pellet 'A'
		28 - fecal pellet 'small A'
		11 - fecal pellet 'B'
		20 - unconsolidated fecal pellets
		64 - crustacean exoskeletons
		2 - harpacticoid copepods
	Filter 29	70 - fecal pellet 'A'
		49 - fecal pellet 'small A'
		7 - fecal pellet 'B'
		10 - unconsolidated fecal pellets
		62 - crustacean exoskeletons
		3 - gammarid amphipods
		2 - harpacticoid copepods
	Filter 32	62 - fecal pellet 'A'
		27 - fecal pellet 'small A'
		5 - fecal pellet 'B'
		7 - unconsolidated fecal pellets
		26 - crustacean exoskeletons
22 May	Filter 34	78 - fecal pellet 'A'
		67 - fecal pellet 'small A'
		7 - fecal pellet 'B'
		10 - unconsolidated material
		9 - crustacean exoskeletons
		1 - gammarid amphipod
		2 - calanoid copepod
	Filter 35	44 - fecal pellet 'A'
		69 - fecal pellet 'small A'
		5 - fecal pellet 'B'
		15 - unconsolidated material
		1 - crustacean exoskeletons
		1 - isopod
	Filter 36	29 - fecal pellet 'A'
		50 - fecal pellet 'small A'
		11 - fecal pellet 'B'
		41 - crustacean exoskeletons
		1 - isopod
		2 - ? eggs

Table 29. con't.

Sample Date	Collection Number	Material
29 May	Filter 42	49 - <b>fecal</b> pellet 'A'
		107 - fecal pellet 'small A'
		5 - fecal pellet 'B'
		4 - unconsolidated fecal pellets
		15 - crustacean exoskeletons
	Filter 43	51 - fecal pellet 'A'
		62 - fecal pellet 'small A'
		12 - fecal 'pellet 'B'
		3 - <b>unconsolidated</b> fecal pellets
	Filter 46	4 - crustacean exoskeletons
		44 - fecal pellet 'A'
		90 - fecal pellet 'small A'
		5 - fecal pellet 'B'
		2 - unconsolidated fecal pellets
		4 - crustacean exoskeletons
		1 - egg
5 June 80	Filter 50	2 - fecal pellet 'A'
		1 - fecal pellet 'small A'
		20 - unconsolidated fecal pellets
		1 - gammarid amphipod
	Filter 52	1 - fecal pellet 'B'
		37 - unconsolidated fecal pellets
	Filter 56	7 - fecal pellet 'A'
		7 - fecal pellet 'small A'
		1 - fecal pellet 'B'
		34 - unconsolidated fecal pellets
		6 - crustacean exoskeletons

Table 30. Total particle flux to the sediment per unit area per day.

Total Particle Counts	
Sample Date	Particle Flux/m <sup>2</sup> /day
24 April 1980	1627 ± 768
3 May 1980	1564 ± 799
11 May 1980	2212 ± 484
22 May 1980	1648 ± 144
29 May 1980	2010 ± 325
5 June 1980	611 ± 253

Table 31. Flux Rate of Major Particle Types.

Sample Date	Collection Number	Flux/m <sup>2</sup> /day				Crustacean Exoskeleton
		Fecal Pellet 'A'	Fecal Pellet 'small A'	Fecal Pellet 'B'		
24 Apr 80	Filter 11	806	47	<b>111</b>		47
	Filter 12	1643	142	158		395
	Filter 14	648	158	<b>126</b>		158
	Average $\pm$ s.d. =		116*60	132 $\pm$ 24		200 $\pm$ 178
3 May 80	Filter 18	632	316	32		205
	Filter 19	269	158	<b>174</b>		16
	Filter 20	537	253	63		1390
	Average $\pm$ s.d. =		242 $\pm$ 80	90 $\pm$ 75		537 $\pm$ 745
11 May 80	Filter 26	737	369	145		843
	Filter 29	922	645	92		816
	Filter 32	816	355	66		342
	Average $\pm$ s.d. =		456 $\pm$ 164	101 $\pm$ 40		667 $\pm$ 282
22 May 80	Filter 34	880	756	79		102
	Filter 35	496	779	56		11
	Filter 36	327	564	124		462
	Average $\pm$ s.d. =		700 $\pm$ 118	86 $\pm$ 35		192 $\pm$ 239
29 May 80	Filter 42	645	<b>1409</b>	66		198
	Filter 43	672	<b>816</b>	158		53
	Filter 46	579	1185	66		53
	Average $\pm$ s.d. =		1137 $\pm$ 299	97 $\pm$ 53		101 $\pm$ 84
5 June 80	Filter 50	32	0	<b>16</b>		0 "
	Filter 52	0	0	16		0
	Filter 56	111	111	16		<b>95</b>
	Average $\pm$ s.d. =		37 $\pm$ 64	<b>61 <math>\pm</math> 0</b>		32 $\pm$ 55

Table 32. Sea-Ice 80 Particle Weight Data.

Dry Weights (grams)						
Sample Date	Collection Number	Filter + Sample	Pre-fired Filter Wt.	Uncorrected Sample Wt.	Salt Correction (g. NaCl)	Total Sample Weight
24 Apr 80	Filter 11	1.0719	0.8232	0.2487	0.1779	0.0708
	Filter 12	1.1420	0.8206	0.3214	0.2284	0.0929
	Filter 14	1.1544	0.8226	0.3318	0.2176	0.1142
3 May 80	Filter 18	1.1004	0.8220	0.2784	0.2246	0.0538
	Filter 19	1.2598	0.8224	0.4376	0.1452	0.2922
	Filter 20	1.5045	0.8203	0.6842	0.2137	0.4705
11 May 80	Filter 26	1.4047	0.8239	0.5808	0.1414	0.4394
	Filter 29	1.1072	0.8244	0.2828	0.22329	0.0499
	Filter 32	2.0641	0.8167	1.2474	0.2809	0.9665
22 May 80	Filter 34	1.0979	0.8201	0.2778	0.2323	0.0455
	Filter 35	1.2217	0.8221	0.3996	0.1920	0.2076
	Filter 36	1.2223	0.8320	0.3903	0.1638	0.2265
29 May 80	Filter 42	1.2594	0.8243	0.4351	0.2489	0.1862
	Filter 43	1.0821	0.8232	0.2589	0.2137	0.0452
	Filter 46	1.2531	0.8262	0.4269	0.2052	0.2017
5 June 80	Filter 50	0.9115	0.8246	0.0869	0.0493	0.0376
	Filter 52	0.8900	0.8175	0.0725	0.0250	0.0475
	Filter 56	1.1081	0.8298	0.2783	0.0371	0.2412

Table 33. Total Particle Dry Weights

Sample Dates	Mean Particle Weight per collection (grams)	Flux (grams)/m <sup>2</sup> /day
24 April 80	0.0926 + 0.0217	1.46 ± 0.34
3 May 80	0.2722 ± 0.2091	4.30 ± 3.30
11 May 80	0.4852 ± 0.4600	6.39 ± 6.06
22 May 80	0.1599 ± 0.0995	1.80 ± 1.12
29 May 80	0.2444 ± 0.0862	1.90*1.14
5 June 80	0.1088 ± 0.1148	1.72 ± 1.81



Table 34. Sea-Ice '80 Carbon/Nitrogen flux rates, 'Narwhal Island Ice Station.

Sample Date	Collection Number	Flux/m <sup>2</sup> /da y	
		Carbon (mg) $\pm$ S.D.	Nitrogen (mg) $\pm$ S.D.
24 Apr	Filter 11	25.45 $\pm$ 5.08	0.33 $\pm$ 0.40
	Filter 12	<b>59.12</b> $\pm$ 13.16	1.48 $\pm$ 0.88
	Filter 14	58.50 $\pm$ 17.74	1.59 * 0.59
	Average	47.69 $\pm$ 20.26	<b>1.13</b> $\pm$ 0.84
3 May	Filter <b>18</b>	33.93 $\pm$ 4.26	1.27 $\pm$ 0.34
	Filter 19	43.71 * 17.09	1.05 $\pm$ 0.51
	Filter 20	43.50 $\pm$ 8.92	2.37 $\pm$ 0.94
	Average	40.37 $\pm$ 11.36	1.56 $\pm$ 0.84
11 May	Filter 26	40.28 $\pm$ 14.04	<b>1.65</b> $\pm$ 0.62
	Filter 29	47.03 $\pm$ 9.16	2.06 $\pm$ 0.90
	Average	43.65 $\pm$ 11.84	1.86 * 0.77
22 May	Filter <b>34</b>	31.67 $\pm$ 7.21	1.39 $\pm$ 0.81
	Filter 35	29.73 $\pm$ 3.75	0.81 $\pm$ 0.43
	Filter 36	25.75 $\pm$ 2.92	<b>1.13</b> $\pm$ 0.72
	Average	29.05 $\pm$ 5.19	1.11 $\pm$ <b>0.65</b>
29 May	Filter 42	29.12 $\pm$ 3.72	1.50 $\pm$ 0.51
	Filter 43	52.34 $\pm$ 8.56	4.92 $\pm$ 0.74
	Filter 46	57.29 $\pm$ 0.60	<b>7.05</b> $\pm$ 1.10
	Average	46.25 $\pm$ 13.890	4.49 $\pm$ 2.50
5 Jun	Filter 50	21.58 $\pm$ 6.95	1.02 $\pm$ 0.40
	Filter 52	20.58 $\pm$ 4.56	0.89 $\pm$ 0.50
	Filter 56	51.31 $\pm$ 10.00	2.03 $\pm$ 1.63
	Average	31.16 $\pm$ 16.36	1.31 $\pm$ <b>1.06</b>

Table 35. Sea Ice-80 Nitrogen Flux, Narwhal Island Ice Station.

Sample Date	Collection Number	Nitrogen Flux/Collector		
		total (mg)	$\text{m}^2$ (mg)	day (mg)
24 Apr	Filter 11	0.021	1.642	0.004
	Filter 12	0.093	7.382	0.019
	Filter 14	0.101	7.965	0.020
3 May	Filter 18	0.080	6.353	0.016
	Filter 19	0.006	5.249	0.013
	Filter 20	0.150	11.863	0.030
11 May	Filter 26	0.125	9.914	0.021
	Filter 29	0.156	12.359	0.026
22 May	Filter 34	0.123	9.699	0.018
	Filter 35	0.071	5.648	0.010
	Filter 36	0.100	7.888	0.014
29 May	Filter 42	0.114	9.024	0.019
	Filter 43	0.374	29.542	0.062
	Filter 46	0.536	42.311	0.089
5 Jun	Filter 50	0.064	5.080	0.013
	Filter 52	0.057	4.466	0.011
	Filter 56	0.128	10.144	0.026

Table 36. Sea Ice-80 Carbon Flux, Narwhal Island Ice Station.

Sample Date	Collection Number	total (mg)	Carbon Flux/Collector m <sub>2</sub> (mg)	day (mg)
24 Apr	Filter 11	1.61	127.18	0.32
	Filter 12	3.74	295.61	0.75
	Filter 14	3.70	292.52	0.74
3 May	Filter 18	2.15	169.63	0.43
	Filter 19	2.77	218.51	0.55
	Filter 20	2.75	217.48	0.55
11 May	Filter 34	3.06	241.70	0.40
	Filter 29	3*57	282.19	0.60
22 May	Filter 34	2.81	221.70	0.40
	Filter 35	2.63	208.12	0.38
	Filter 36	2.28	180.25	0.33
29 May	Filter 42	2.21	174.69	0.37
	Filter 43	3.97	314.04	0.66
	Filter 46	3.25	256.55	0.54
5 Jun	Filter 50	1.37	107.90	0.27
	Filter 52	1.30	102.92	0.26
	Filter 56	3.25	256.55	0.65

Table 37. Sea Ice-80 Carbon/Nitrogen flux rates, Narwhal Island Ice Station.

Sample Date	Collection Number	Flux/m <sup>2</sup> /day	
		Carbon (mg) $\pm$ S.D.	Nitrogen (mg) $\pm$ S.D.
24 Apr	Filter 11	25.45 $\pm$ 5.08	0.33 $\pm$ 0.40
	Filter 12	59.12 $\pm$ 13.16	1.48 $\pm$ 0.88
	Filter 14	58.50 $\pm$ 17.74	1.59 $\pm$ 0.59
	Average	47.69 $\pm$ 20.26	1.13 $\pm$ 0.84
3 May	Filter 18	33.93 $\pm$ 4.26	1.27 $\pm$ 0.34
	Filter 19	43.71 $\pm$ 17.09	1.05 $\pm$ 0.51
	Filter 20	43.50 $\pm$ 8.92	2.37 $\pm$ 0.94
	Average	40.37 $\pm$ 11.36	1.56 $\pm$ 0.84
11 May	Filter 26	40.28 $\pm$ 14.04	1.65 $\pm$ 0.62
	Filter 29	47.03 $\pm$ 9.16	2.06 $\pm$ 0.90
	Average	43.65 $\pm$ 11.84	1.86 $\pm$ 0.77
22 May	Filter 34	31.67 $\pm$ 7.21	1.39 $\pm$ 0.81
	Filter 35	29.73 $\pm$ 3.75	0.81 $\pm$ 0.43
	Filter 36	25.75 $\pm$ 2.92	1.13 $\pm$ 0.72
	Average	29.05 $\pm$ 5.19	1.11 $\pm$ 0.65
29 May	Filter 42	29.12 $\pm$ 3.72	1.50 $\pm$ 0.51
	Filter 43	52.34 $\pm$ 8.56	4.92 $\pm$ 0.74
	Filter 46	57.29 $\pm$ 0.60	7.05 $\pm$ 1.10
	Average	46.25 $\pm$ 13.890	4.49 $\pm$ 2.50
5 Jun	Filter 50	21.58 $\pm$ 6.95	1.02 $\pm$ 0.40
	Filter 52	20.58 $\pm$ 4.56	0.89 $\pm$ 0.50
	Filter 56	51.31 $\pm$ 10.00	2.03 $\pm$ 1.63
	Average	31.16 $\pm$ 16.36	1.31 $\pm$ 1.06



Figure 55. Total glass-fiber filter surface from a particle trap to illustrate general appearance after a six-day deployment at the Narwhal Island Ice Station, 1980. Note the exclusion of the filter edge for analysis.



Figure 56. Enlargement of "large" fecal pellet from the particle trap glass-fiber filter pads deployed at the Narwhal Island Ice Station, 1980. Formed by Mysis reli.eta.

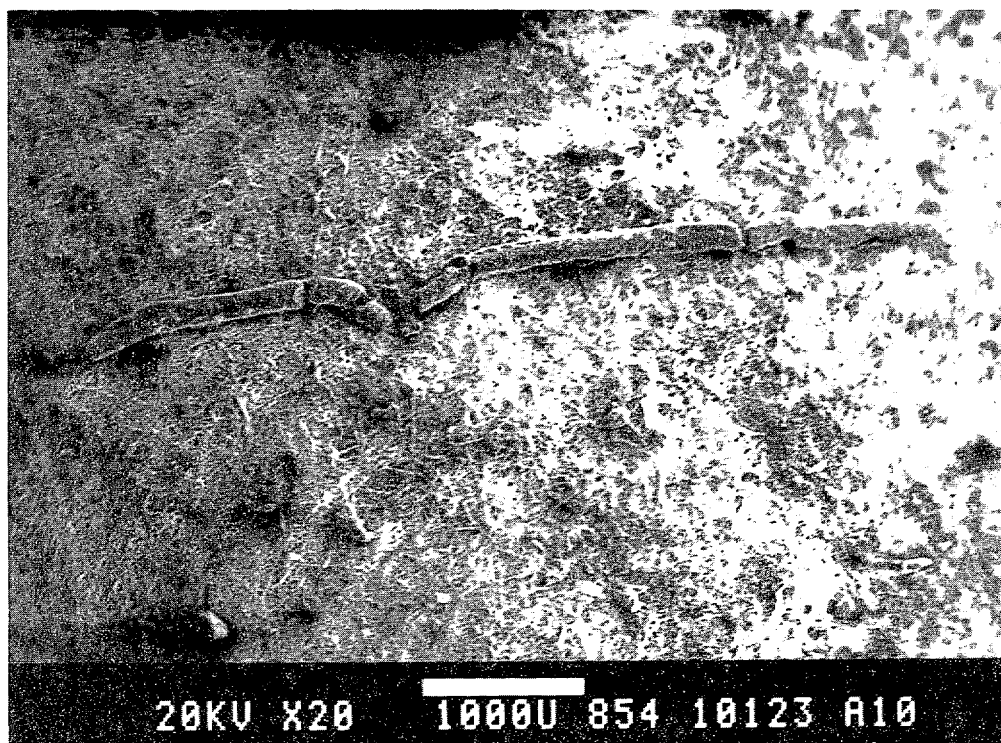


Figure 57. Scanning electron micrograph of Mysis relicta fecal pellet collected by particle trap, Narwhal Island Ice Station, 1980.

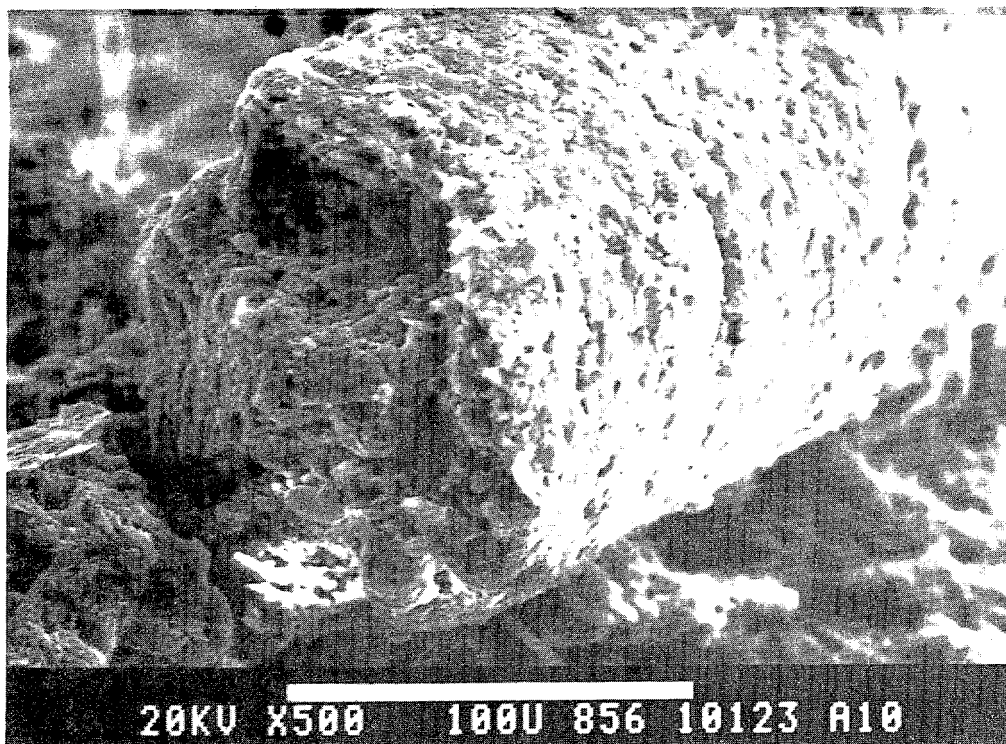


Figure 58. Detail of broken end of *Mysis relicts* fecal pellet collected by particle trap at the Narwhal Island Ice Station, 1980



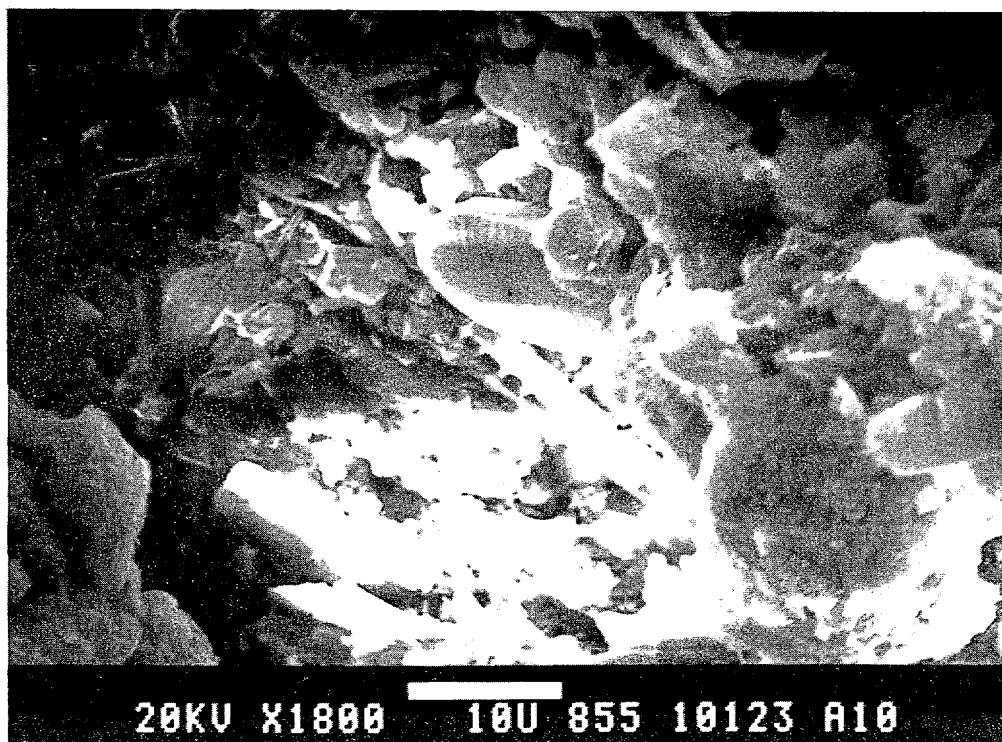


Figure 59. Further detail of broken end of *Mysis relicts* fecal pellet collected by particle trap at the Narwhal Island Ice Station, 1980. Note the heterogeneity and fragmented nature of the pellet contents.



Figure 60. Scanning electron micrograph of "small" fecal pellets collected by particle trap at the Narwhal Island Ice Station, 1980. Formed by Pseudalibrotus litoralis.

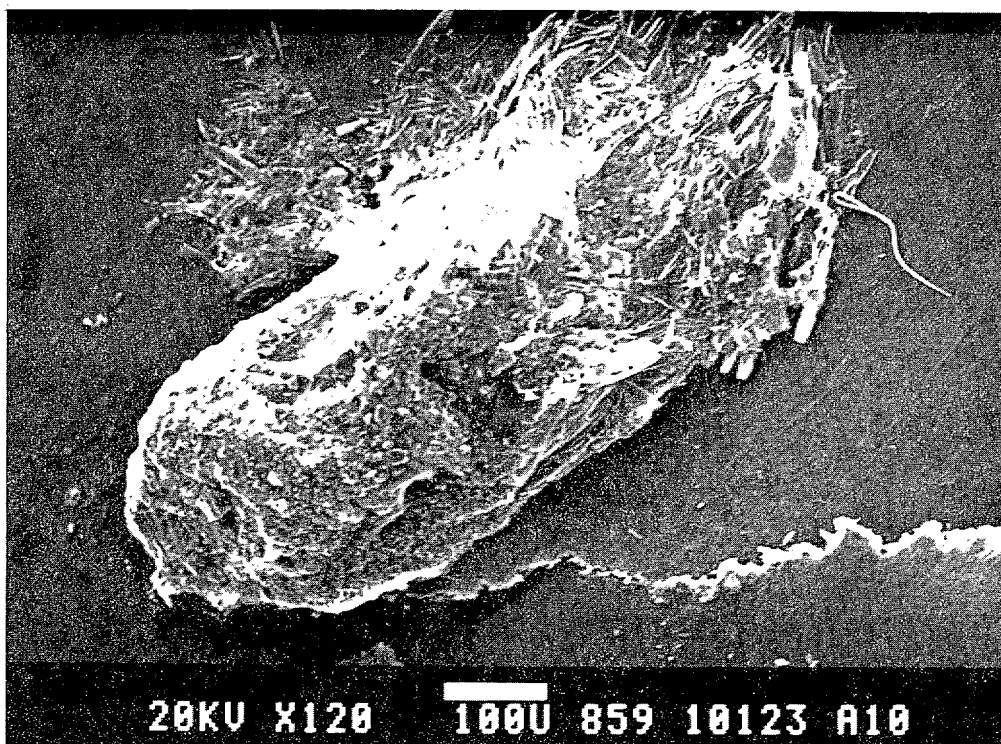


Figure 61. Scanning electron micrograph of a squashed preparation of a *Pseudalibrotus litoralis* fecal pellet collected by particle trap, Narwhal Island Ice Station, 1980. Note the diatom test composition.

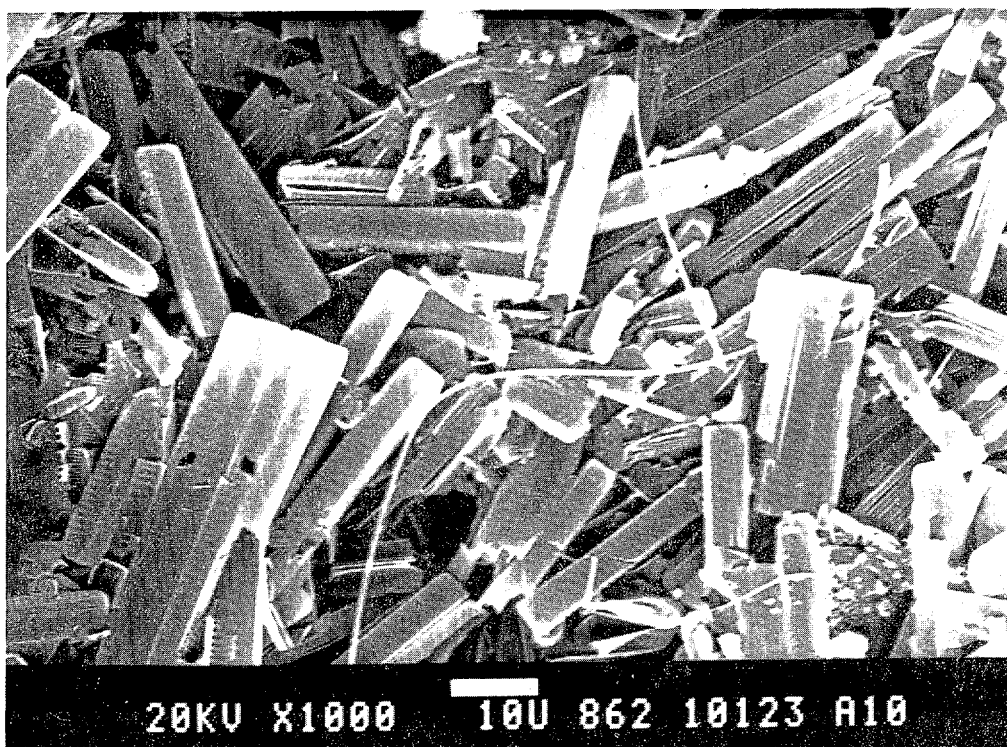


Figure 62. Detail of the diatom tests that completely fill the Pseudalibrotus litoralis fecal pellet in Fig. 61 .  
Collected at the Narwhal Island Ice Station, 1980.

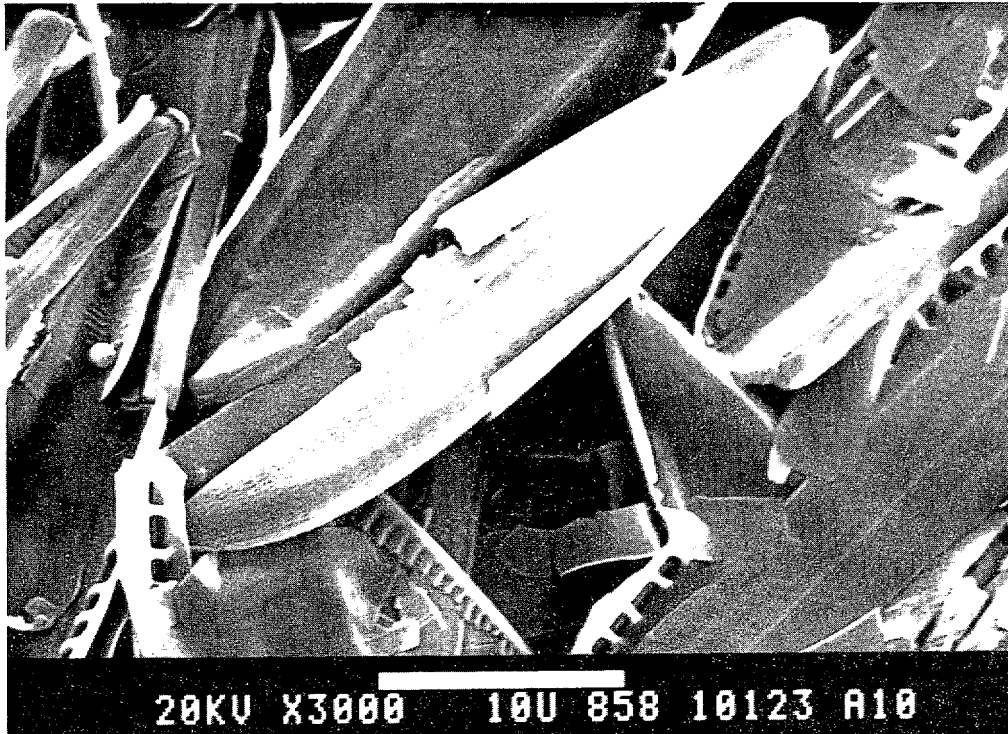


Figure 63. Additional detail of diatom test fragments that completely fill the Pseudalibrotus litoralis fecal pellet in Fig. 61. Collected at the Narwhal Island Ice Station, 1980.



Appendix IV: Voucher material submitted to the Marine Invertebrate Zoology section, California Academy of Sciences.

Table 38. List of Polychaeta: Annelida species submitted to the OSCEAP Voucher Collection, California Academy of Sciences

**Aglaophamus malmgreni**  
*Allis* nr **suecica**  
*Amage auricula*  
*Ampharete acutifrons*  
*Ampharete arctica*  
*Ampharete goësi*  
*Ampharete vega*  
*Amphicteis sundevalli*  
*Anaitides groenlandica*  
**Antinoella sarsi**

*Apistobranhus tullbergi*  
*Arcteobia anticostiensis*  
**Arenicola glacialis**  
*Aricidea quadrilobata*  
*Artacama proboscidea*  
**Autolytus alexandri**  
**Autolytus fallax**  
*Axionice maculata*  
**Barantolla** sp.  
*Brada inhabilis*

*Brada villosa*  
**Capitella** capitata  
*Chaetozone setosa*  
**Chone** duneri  
*Chone infundibuliformis*  
**Chone** nr **murmanica**  
**Cistenides hyperborea**  
*Clymenura polaris*  
**Cossura longocirrata**  
**Diplocirrus glaucus**

**Diplocirrus hirsutus**  
**Diplocirrus longisetosus**  
*Dorvillea* sp.  
*Enipo canadensis*  
*Eteone longis*  
*Euchone analis*  
*Euchone elegans*  
*Euchone incolor*  
*Euchone papillosa*  
*Eucranta villosa*

*Eunoe oerstedii*  
*Eusyllis blomstrandii*  
*Exogone naidina*  
*Flabelligera affinis*  
*Gattyana 'cirrosa*  
*Glycera capitata*

**Glycinde wireni**  
**Glyphanostomum pallescens**  
*Harmothoe imbricata*  
**Heteromastus filiformis**  
*Lagisca extenuata*  
**Lanassa venusta**  
*Laonice cirrata*  
*Laonome kroyeri*  
*Laphania boeckii*  
**Leitoscoloplos acutus**

*Levinsenia gracilis*  
*Lumbrineris fragilis*  
*Lumbrineris impatiens*  
**Lumbrineris latreilli**  
*Lumbrineris minuta*  
*Lumbrineris* sp. A  
**Lysilla loveni**  
*Lysippe labiata*  
**Magelona longicornis**  
**Maldane sarsi**

**Marenzelleria wireni**  
**Melaenis loveni**  
*Melinna cristata*  
**Microclymene** sp.  
**Micronephthys minuta**  
**Microspio theeli**  
**Minuspio cirrifera**  
**Myriochele heeri**  
*Myriochele oculata*  
*Mystides borealis*

**Nemidia torelli**  
*Nephtys ciliata*  
*Nephtys longosetosa*  
*Nephtys paradoxa*  
*Nereimyra aphroditoides*  
*Nereis zonata*  
**Nicolea zostericola**  
*Nothria conchylega*  
**Notomastus latericeus**  
**Onuphis quadricuspis**

**Ophelina acuminata**  
**Ophelina cylindricaudatus**  
**Ophelina groenlandica**  
*Ophryotrocha* sp.  
**Owenia collaris**  
*Paramphitrite tetrabranchia*



Table 38. List of Polychaeta: Annelida species submitted to the OSCEAP Voucher Collection, California Academy of Sciences (cont'd)

*Paranaitides wahlbergi*  
*Parheteromastus* sp. A  
*Petaloproctus tenuis*  
*Pherusa plumosa*  
*Pholoe minuta*  
*Pionosyllis compacta*  
*Pista cristata*  
*Polycirrus medusa*  
*Polydora caulleryi*  
*Polydora quadrilobata*  
  
*Polydora socialis*  
*Polyphysia crassa*  
*Praxillella gracilis*  
*Praxillella praetermissa*  
*Prionospio steenstrupi*  
*Proclea graffii*  
*Pygospio elegans*  
*Rhodine gracilior*  
*Sabellastarte* sp.  
*Scalibregma inflatum*  
  
*Schistomeringos caeca*  
*Scoloplos armiger*  
*Sigambra tentaculata*  
*Sphaerodoridium* sp. A  
*Sphaerodoropsis biserialis*  
*Sphaerodoropsis minuta*  
*Sphaerodoropsis* sp. A  
*Sphaerodorum gracilis*  
*Sphaerosyllis erinaceus*  
*Spio filicornis*  
  
*Spiochaetopterus typicus*  
*Spiophanes bombyx*  
*Sternaspis scutata*  
*Syllides longocirrata*  
*Terebellides stroemi*  
*Tharyx ?acutus*  
*Travisia* sp.  
*Trichobranchus glacialis*  
*Trochochaeta carica*  
*Trochochaeta multisetosa*  
  
*Typosyllis cornuta*  
*Typosyllis fasciata*

Table 39.

Pelecypod voucher specimens sent to California Academy of Sciences

<u>Species</u>	<u>Smith/McIntyre grab number</u>	<u>Specimens</u>
<u>Nucula bellotii</u>	1436-11	1
<u>Nucula bellotii</u>	1462-11	2
<u>Nuculana minuta</u>	1546-18	1
<u>Nuculana pernula</u>	1630-15	1 + 1 pair valves
<u>Nuculana radiata</u>	1102	1 pair valves
<u>Portlandia arctica</u>	1434-13	11 + valves
<u>Portlandia frigida</u>	1448-13	2
<u>Portlandia lenticula</u>	1639-15	7 + 3 valves
<u>Yoldia hyperborea</u>	1378-07	1 broken pair valves
<u>Yoldia myalis</u>	1374-08	1 broken pair valves
<u>Bathyarca glacialis</u>	1643-14	1
<u>Crenella decussata</u>	1448-13	1
<u>Dacrydium vitreum</u>	1646-14	7 + 2 pair 3 valves
<u>Musculus corrugates</u>	1637-16	1
<u>Musculus discors</u>	1089	2
<u>Musculus niger</u>	1085	2 valves
<u>Arctinula greenlandica</u>	1456-09	5 + 2 pair valves
<u>Axinopsida orbiculata</u>	1454-11	6
<u>Thyasira equalis</u>	1624-13	6 + 2 pair valves
<u>Thyasira gouldii</u>	1093	4
<u>Mysella planata</u>	1342-14	1
<u>Cyclocardia crebricostata</u>	1123-19	1
<u>Astarte crenata</u>	1647-14	2 valves
<u>Astarte borealis</u>	1339-16	1
<u>Astarte montagui</u>	1577-15	6
<u>Clinocardium ciliatum</u>	1545-16	1
<u>Serripes groenlandicus</u>	1107-12	1 matched pair + 1 valve
<u>Macoma calcarea</u>	1470-15	18
<u>Macoma loveni</u>	1557-12	1
<u>Macoma moesta</u>	1334-14	2
<u>Liocyma fluctuosa</u>	1386-10	19 + 1 pair valves
<u>Mya pseudoarenaria</u>	1475-10	1 pair valves
<u>Hiatella arctica</u>	1437-07	1
<u>Pandora glacialis</u>	1468-13	6
<u>Lyonsia arenosa</u>	1469-12	2 matched pair + 2 valves
<u>Periploma aleutica</u>	1578-11	1
<u>Thracia devexa</u>	1647-14	1 pair valves
<u>Cuspidaria glacialis</u>	1641-16	1